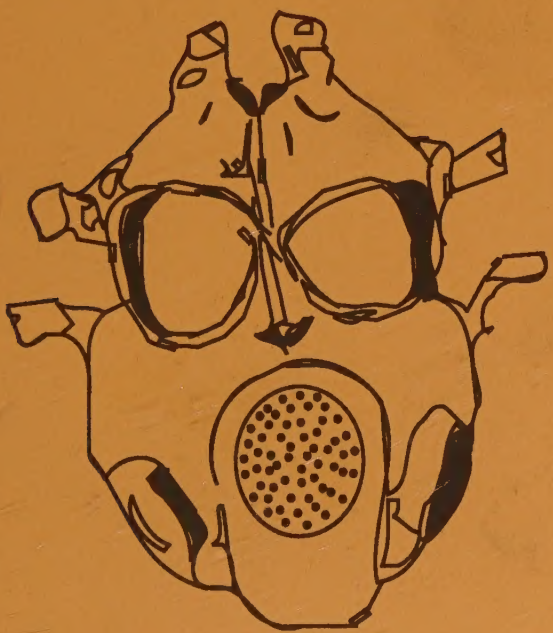
Guide to Germ Warfare



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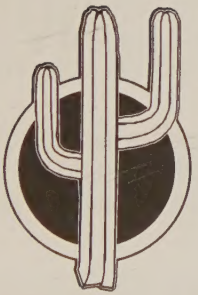

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Guide To Germ Warfare

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TECHNICAL MANUAL
No. 3–216

AIR FORCE MANUAL
No. 355–6

DEPARTMENTS OF THE ARMY AND
THE AIR FORCE
WASHINGTON 25, D. C., *11 January 1956*

MILITARY BIOLOGY AND BIOLOGICAL WARFARE AGENTS

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CHAPTER 1
INTRODUCTION

1. Purpose

This manual provides a source of information on aspects of biology having military application and on the types of biological agents which might be used against us. Although this manual is intended primarily for use by chemical officers in accomplishment of their mission, all commanders of ground and air forces should be familiar with it in order that they may realize the dangers of biological warfare (BW) and how such warfare may be recognized and combated.

2. Scope

a. This manual contains examples of possible biological agents of various types that might be used against man, animals, and plants and includes a description of the properties of each. A study of this information will indicate capabilities and limitations of these agents. The discussion on dissemination is limited to various procedures which might be used in launching a BW attack.

b. The discussion of agents in this manual is not indicative of specific agents that the enemy may have under consideration, nor does it include the whole range of materials which could conceivably have offensive value.

c. The subjects of laboratory identification of biological warfare agents and the prevention and treatment of diseases caused by such agents are the responsibilities of the medical services and are not included as such in this manual.

3. Definition of Biological Warfare Terms

a. Biological warfare (BW) is the military use of living organisms or their toxic products to cause death, disability, or damage to man, his domestic animals, or crops.

b. The term "biological warfare" is preferred to "bacteriological warfare" or "germ warfare" because it includes the employment not only of bacteria but also of other micro-organisms and higher forms of life, such as insects and other pests.

c. Biological warfare agents include living organisms or their toxic products.

d. While certain chemical anticrop compounds are not truly biological warfare agents, they are so considered as a matter of convenience.

4. Objectives of BW

The primary object of BW attack is man. The attack upon him is either direct or it is indirect through limitation of his food supply or, in some instances, by destruction of his domestic animal transportation. BW is antipersonnel warfare, but not antimateriel warfare, in that housing, buildings, factories, and other structures remain intact and can be made useful in a short time.

5. Misconceptions of BW

a. Many rumors and published articles have made sensational claims that biological (germ) warfare could wipe out all forms of life in a community. Often these rumors and articles have been based on misconceptions which have in turn led to misrepresentation and to misunderstanding. There is no germ or biological agent which can wipe out all forms of life in a community. In order to accomplish these sensational claims, it would be necessary for each individual to be susceptible to the micro-organism (germ) or toxin employed and for him to be exposed to an effective amount of the agent. It is obvious that neither of these conditions is likely to exist. A number of persons in any given population are always partially or completely immune to any specific disease, and it would be unlikely that great areas could be completely blanketed in a BW attack.

b. From the earliest time man has been continually fighting a defensive battle against micro-organisms, in the form of disease, and has been able to survive through development of immunity, improvement in sanitation and nutrition, and the progress of medical science. The use of micro-organisms as BW agents is simply a military adaptation of naturally occurring biological attacks. The suffering caused by most diseases is no greater than that caused by severe injuries inflicted by shell fragments or machinegun fire; the chances of complete recovery from infectious diseases are usually much greater than from injuries caused from other types of warfare. It has also been asserted that new, horrible diseases will be unleashed if BW occurs; this claim is obviously not true as man can work only with existing micro-organisms.

c. Because naturally occurring epidemics have caused tremendous havoc to mankind in the past, it has been asserted frequently that artificially induced epidemics could be produced in the future by attack with various biological agents. However, since epidemics tend to spread slowly, they probably can be effectively controlled or prevented by modern sanitation, hygiene, quarantine, immunization, or treatment measures; hence, widespread explosive epidemics are not expected to result from BW attacks against highly civilized populations unless there has been severe disruption of medical and sanitary facilities.

d. It is true that BW attacks the noncombatant population as well as the Armed Forces; this is equally true of attack on a city by aircraft with high explosive or atomic bombs or by artillery shell. BW attack on sources of food, such as livestock and crops, might produce serious effects through destruction of only a small fraction of the supply, where the margin between supply and demand is very small. Destruction or incapacitation of a significant proportion of military or civilian personnel in a given situation also might be a determining factor. In such a case, victory might be achieved with a minimum sacrifice of human life by either side. In any event, cities, factories, homes, and other attributes of civilization would not be destroyed, and rehabilitation would be much more easily effected than after conventional bombing attacks.

CHAPTER 2

BIOLOGY OF MILITARY SIGNIFICANCE

Section I. INTRODUCTION

6. General

a. Although biological warfare agents have never been used as a significant weapon of war, there is factual evidence that they have been used in some form since early times. In the middle ages war parties dropped plague-ridden corpses into wells of their enemy. This type of warfare was practiced particularly in desert warfare where wells were of strategic importance and easily contaminated. During the French and Indian War, 1763, the British infected the Indians with smallpox by giving them blankets and handkerchiefs taken from infected patients —approximately 95 percent of the Indians that were exposed died of the disease. In World War I, German agents inoculated horses and cattle shipped from the United States to the Allies with disease-producing bacteria; the Germans also used glanders against the Rumanian Cavalry. In 1940, claims were made by the Chinese that Japanese planes had dropped plague-infested fleas wrapped in little cotton bags containing grain. It was assumed that their purpose was to initiate an epidemic of plague by utilizing their natural vectors. In the past, widespread natural disease epidemics have decimated the populations of various areas and, in many wars, infections and disease have caused more casualties than have weapons.

b. Since BW has never been used on a major scale, no definite evaluation can be made of its effectiveness as a weapon of war. The fact that very little is known of the potential tactical or strategical value of BW in modern warfare should not lead to an underestimation of its possibilities. It has been fairly well established that BW agents can be produced on a scale not considered possible in the past. Any small nation having modern and adequate research facilities could produce BW agents on a small scale. The cost of the development of large-scale BW would be much less than that incident to some other weapons of war. It is also possible that new and effective methods for artificial dissemination of disease-producing agents may be developed. For these reasons, BW must be assumed to present a potentially dangerous form of attack. Some basic knowledge of the principles of biology and of the properties of biological agents is essential for the appreciation of their military significance, so that preparations can be made to render BW attacks, should they occur, as ineffective as possible.

7. Military Biology

a. Although the science of biology deals with all living organisms, military biology is concerned only with those which will adversely affect man, animals, or plants. Certain chemical anticrop compounds are included in this category, because research on these agents is more conveniently handled in biological laboratories.

b. The following five general groups, because they appear to have military significance, have been classed as BW agents and will be considered in this chapter.

(1) Micro-organisms (bacteria, viruses, rickettsiae, fungi, protozoa).

(2) Toxins (microbial, animal, plant).

(3) Vectors of disease—arthropods (insects and acarids), other animals.

(4) Pests (of animals and plants).

(5) Chemical anticrop compounds (plant growth inhibitors, herbicides, defoliants).

Section II. CHARACTERISTICS OF MICRO-ORGANISMS

8. General

a. Description. Micro-organisms are minute living organisms, usually microscopic (that is, too small to be seen by the unaided eye). When magnified 500 to 1,000 times by the microscope, each micro-organism is found to be composed of a single cell or a group of associated cells, each of which is capable of carrying on all the functions of life, including growth and reproduction. Lacking a digestive tract, the micro-organism acquires food in soluble form through the moist membrane which surrounds the cell contents. Not possessing organs of sight, it does not differentiate between light and darkness by the visual method. Having no heat regulating system, it assumes the temperature of its surroundings. Many of the micro-organisms resemble plant life and are regarded as members of the vegetable kingdom, while others, including the protozoa, have characteristics which cause them to be placed in the animal kingdom.

b. Classification. On the basis of structure and behavior characteristics, micro-organisms may be divided as follows (in order of size): fungi, protozoa, bacteria, rickettsiae, and viruses. Viruses, the smallest of the micro-organisms, can be seen only when photographed by the electron microscope. Micro-organisms are so small that the unit applied in their measurement is the micron, which is equivalent to 0.001 millimeter or approximately 1/25,000 of an inch.

c. Pathogenicity. Micro-organisms capable of producing disease are called pathogens. Most of the pathogens are parasites, since they live

in, on, or with some other living host at whose expense they obtain food and shelter. Organisms which multiply in dead rather than in living matter are called saprophytes; while most of these are harmless, some produce poisonous products which cause disease. Examples of some of these harmful saprophytes are the bacteria which cause tetanus, producing their poison in macerated, devitalized tissue, and those which cause botulism, manufacturing their toxin in food outside of the body.

d. Utility. Most micro-organisms are nonpathogenic, and many are beneficial to animal and plant life. From the secretions of certain micro-organisms some of the most powerful antibiotics, such as chloromycetin, penicillin, and streptomycin, have been obtained. Micro-organisms are important in the preparation of dairy products and in the fermentation industry (for example, rising of bread and production of vinegar and alcoholic beverages). Soil fertility is largely dependent upon their activity in decomposing dead organic matter and releasing the elements needed for the growth of plants.

e. Distribution. Micro-organisms are universally distributed in the air, water, and soil. Soil organisms are found in all surfaces exposed to dirt and dust, and every cubic foot of topsoil provides the natural home for billions of them. The skin, hair, nose, mouth, and digestive tract of man and animals harbor a considerable variety of micro-organisms in large numbers. However, the pathogenic, or disease-producing organisms of man, animals, and plants, with very few exceptions, usually do not survive long or grow well in the absence of a suitable host, and favorable environmental conditions are necessary for their survival.

9. Growth and Survival

Numerous factors influence the growth of micro-organisms, which are more dependent on a delicately adjusted environment than are higher forms of life. Some of their requirements are presented below.

a. Moisture. A plentiful supply of water is essential, as this amounts to about nine-tenths of the cellular substance, and is the vehicle by means of which soluble food is made available by diffusion through the cell wall. It also is required in the immediate surroundings to prevent drying of the organism; even a small decrease may interfere with normal functions and cause death. However, it is possible to keep even quite delicate organisms alive by lyophilization, which is a combined process of quick freezing and drying at very low temperatures.

b. Food. Food is required to supply building material and energy. Micro-organisms in general can utilize a wide variety of substances, including proteins, sugars, mineral salts, and vitamins, but the requirements of different species are not the same, either in the kinds of food or in their proportions. As mentioned previously, the parasites

normally feed on living plants or animals but, under favorable conditions, some will grow in foodstuffs or artificial media; the saprophytes require dead or decaying organic matter. The viruses and rickettsiae will grow *only* in the presence of living host cells; thus they are obligate parasites.

c. Oxygen. As with higher forms of life, all micro-organisms require oxygen to live, but they may differ markedly in respect to the sources from which they obtain it. Those which will grow only in the presence of free oxygen are called obligate aerobes, while those which grow only in the absence of free oxygen are termed obligate anaerobes and obtain their oxygen in the combined form from various chemical compounds. Lying between these two extremes are the facultative aerobes, which are fundamentally anaerobes but can grow in the presence of free oxygen, and the facultative anaerobes, which are essentially aerobes but can grow in the absence of free oxygen. Most of the pathogenic micro-organisms are facultative because they may obtain their oxygen in either form. In either case, the supply of oxygen is essential to provide energy and to aid in the formation of new cellular material.

d. Temperature. Temperature is an important factor, each species of organism developing most abundantly at a particular or optimum temperature range. Pathogens of warm-blooded animals develop best in the narrow temperature ranges common to these animals. At variations either below or above this range, the organism functions progressively less effectively until temperatures are reached at which growth no longer occurs. High temperatures are fatal, but survival often occurs at low temperatures. Climatic conditions might be decisive factors in determining whether certain micro-organisms could be used in desert or arctic warfare.

e. Light. Most micro-organisms do not require light for growth. They are destroyed by prolonged direct exposure to ultraviolate rays from the sun or from artificial sources. Consequently, growth occurs best in the dark, or at least in an environment protected from direct sunlight.

f. Reaction of Medium. In general, most micro-organisms associated with animal life grow best in neutral or slightly alkaline surroundings, while those associated with plant life often prefer a slightly acid environment. Growth is inhibited by either highly acid or highly alkaline surroundings.

g. Time. When micro-organisms are placed in a new environment, there is a period of adjustment or lag phase in which the number of cells does not increase appreciably. If all essential factors are favorable and there is no opposition from the host, an insignificant number of organisms may develop within a few hours, or at most, days, into numbers almost beyond comprehension.

h. Encapsulation. The formation of capsules, a process known as encapsulation, is a property of many bacteria which may favor their survival. The capsule is also associated with virulence in a variety of pathogenic bacteria. For example, pneumococci that are encapsulated are highly virulent whereas when they have no capsule they are relatively avirulent. Anthrax baccilli are almost always found to be encapsulated when observed in preparations made from animal tissues. The capsule appears to function as a bacterial defense against the activity of phagocytic cells of the body. The capsule apparently originates from the outer layer of the cell membrane and consists of a thick, colorless (translucent) outer wall of gelatinous (protein), gummy (polysaccharide), or fatty material. There is good reason to believe that capsule formation may be stimulated by unfavorable environmental conditions such as the resistance of an infected host.

i. Sporulation. Another protective mechanism favorable to survival among bacteria is sporulation, which leads to the formation of heavy-walled bodies called spores. Sporulation is not necessarily a response to unfavorable conditions, since spores are often formed early in the life of a culture while conditions are wholly favorable to continued vegetative activity. Bacterial spores are more resistant to injurious or unfavorable influences (such as starvation, high and low temperatures, germicidal chemicals, drying, and oxidation) than the growing or vegetative forms. When the spore has matured, the surrounding vegetative form disintegrates. The resistant spore thus formed may remain dormant for years without food or water, and under extreme ranges of temperature, and again develop into an actively growing vegetative cell when conditions become favorable. Spore formation is not a method of multiplication in the bacteria, for each vegetative cell forms only a single spore and each spore germinates into a single vegetative cell. Therefore, it is considered a means for the perpetuation of the organism. Since the rate of growth of certain species is accelerated after spore formation, the process may serve to rejuvenate the activities of the bacterial cell. In higher fungi, such as molds and mushrooms, spore formation, either sexual or asexual, is the normal method of reproduction.

10. Reproduction

Reproduction may be asexual or sexual, depending on the microorganism concerned, but the asexual process is the more common.

a. Asexual. Asexual reproduction may occur by binary fission, by budding, or by sporulation. In binary fission, the cell divides into two equal and identical parts, each of which develops into a new organism. In budding, a small portion of the parent cell is pinched off and develops into a new, actively growing individual. In fungal sporula-

tion, special cells are set aside for reproduction. The bacteria reproduce by asexual binary fission; the yeasts, which belong to the fungi, reproduce sometimes by asexual binary fission but usually by budding or by sexual spore formation. The higher fungi usually reproduce by sporulation. Protozoa may reproduce by fission, but sexual reproduction is common in certain species. Methods by which viruses and rickettsiae reproduce have not been satisfactorily established.

b. Sexual. Sexual methods of reproduction are often encountered among micro-organisms. These involve copulation of two cells with interchange of cellular contents, usually resulting in the formation of spores of various types. Sexual reproduction is known to occur among the fungi and protozoa, although it is often difficult to identify the cells as male or female.

11. Identification

The methods involved in the identification of most micro-organisms are difficult and time-consuming and usually are dependent upon obtaining living organisms. As organisms exhibit preferences for environments in which they will grow (that is, the type of material required for their survival), information as to the source of the organism is of value in establishing its identity. Usually, such information will not be available under conditions of BW. Laboratory procedures are used to establish or confirm the identity of a micro-organism. A few of these methods are described below.

a. Sampling. Rapid identification of a micro-organism used as a BW agent is dependent upon sampling procedures capable of obtaining a large number of viable organisms relatively free from interfering materials or other organisms. Methods of collecting suspected material vary with its nature and source, that is, living or dead tissue, body secretions, soil, air, water, surfaces of all kinds, and with methods of its release, such as aerosols from various spraying devices or bombs. If the agent is released as an aerosol (cloud or spray), every effort should be made to obtain an air sample as near the point of release as possible. The number as well as the viability of the organisms released in an aerosol will decrease progressively with the passage of time and with increasing distance from the point of release outward. Also the original aerosol is relatively uncontaminated, since there are few naturally occurring organisms in the air. Samples of vegetation, water, soil, and other material on which the agent has fallen may be of value in aiding or helping confirm the identity of the agent even though the samples contain interfering contamination and yield a smaller number of organisms than are found in the original aerosol. Such samples should be taken if battle conditions or other factors make it impossible to obtain air samples of the original aerosol or if

there is evidence that a poorly representative sample might have been taken. These samples should be taken as soon after release and as near the point of release as possible. Air samples may be obtained by drawing the air through impingers or bubblers, by bringing the air in contact with the surface of nutrient media, or by using special filtering devices. Vegetation, water, and soil samples are obtained by placing portions of each in sterile containers. Samples from other contaminated surfaces may be obtained by rubbing the surfaces with a sterile cotton swab and placing the swab in a sterile capped container. The samples are then sent, by the fastest method available, to the nearest designated laboratory for identification. Details of sampling and detection of BW agents are described in circulars or manuals on defensive measures.

b. Microscopic Examination. Micro-organisms (except viruses and rickettsiae) in smears or suspensions of suspected material may be examined and counted under a microscope for identification purposes. Such examinations may be aided by staining the micro-organisms with dyes, which bring into sharper detail the shape, relative size, and presence of spores, capsules, or flagella of certain micro-organisms which otherwise might not be noted. A very important staining procedure is the Gram method. In this process the specimens are first stained, then exposed to a decolorizing fluid, and subsequently counterstained. Organisms retaining the primary stain are called gram-positive, and those stained by the secondary stain are gram-negative.

c. Culture. Micro-organisms may be cultivated by placing samples of them in sterile containers holding solid or liquid nutrient media and incubating them at temperatures suitable for growth for specific lengths of time. Organisms multiplying on solid media form visible masses or colonies whose surface appearance, shape, and color help in their identification. In liquid media, identification of the micro-organism is aided by determining what kinds of food are required for its growth and what substances it produces. Cultivation of the viruses and rickettsiae requires the presence of living, suspectible host tissues.

d. Tests. Micro-organisms may be identified biochemically by cultivation of them in certain media, observation of the byproducts of their growth, and determination of what materials they consume. By the addition of certain chemical compounds to the media, it is possible also to differentiate between different kinds of micro-organisms by unequally influencing their growth. Biological tests are also practicable for identifying many micro-organisms. Suitable animals are injected with the suspected organism, and clinical or post-mortem observations of pathological changes are made. When a certain kind of organism is under suspicion, it may be inoculated into animals which have been immunized against it and into an equal number of nonimmunized ani-

mals; if the suspicion is correct, the nonimmunized animals will develop the disease, while the immunized animals will not. A third method of identification is by serological testing. This is based upon the occurrence in all living cells of specific protein substances known as antigens which, when introduced into the blood or tissues of a foreign animal body, induce the formation of specifically reacting antagonistic substances known as antibodies. Since antibodies usually appear in the blood serum, which is then used in testing for specific antigens, these antigens-antibody reactions are known as serological reactions. It is possible with serorological reactions to distinguish between different but closely related organisms, thus aiding in the diagnosing of an infectious disease.

12. Inhibition and Destruction

In this text the term "inhibition" is used to indicate arrest in growth or multiplication (reproduction), while destruction refers to death; sterilization is synonymous with destruction. These phenomena may be brought about by physical, chemical, or biological means.

a. Physical.

(1) *Temperature.* High temperatures are effective in destroying micro-organisms. Higher temperatures or longer exposures are required when dry heat is used than when moist heat is used. Direct exposure to flame and to steam under pressure are reliable for sterilizing materials which are not harmed by these methods. Boiling water or flowing steam are effective when resistant species or spores are absent. Some delicate organisms, however, do not survive even small temperature fluctuations of their environment. On the other hand, rapid lowering of the temperature to subfreezing accompanied by quick-drying tends to preserve the life of many micro-organisms, and they survive in a state of suspended animation.

(2) *Desiccation.* Desiccation, or drying, is one of the oldest measures used to prevent spoilage of food by micro-organisms, examples being the production of jerked beef, prunes, powdered milk and eggs, and other dehydrated foods. In the absence of moisture, food cannot diffuse through the cell membrane, and growth of the organism ceases. Vegetative organisms are particularly susceptible to drying, but spores are practically unharmed. Drying may reduce the number of living organisms but cannot be relied upon for their complete destruction.

(3) *Starvation.* Growth can be inhibited and sometimes death induced when essential food materials are removed or rendered unavailable. All micro-organisms require oxygen, carbon, nitrogen, and hydrogen in some form; if any one of these elements is eliminated or converted to an unusable form, the

micro-organism cannot develop and may eventually die. Varying amounts of other materials too numerous to name in this text also are essential, depending on the kind of organism involved. Spores, as opposed to vegetative forms, can remain dormant for long periods without food; hence spores may not be killed by starvation, but their germination may be prevented.

(4) *Light.* Ultraviolet rays from the sun or artificial sources quickly destroy exposed micro-organisms, but these rays have low penetrating powers and may be ineffective against microbes protected by thin liquid or dust films, rough surfaces, or opaque liquids.

(5) *Filtration.* Micro-organisms can be removed from air and liquids by various filtering devices. The efficiency of filtering processes depends not only on the kind of filter used but also upon such factors as particle size and number of organisms present, electrostatic charge, and rapidity of filtration. The larger organisms may be removed by filtration through asbestos pads, collodion, or other specially prepared membranes, filter paper, or unglazed porcelain, the pore sizes of which are too small to permit passage of the micro-organisms. Some micro-organisms, such as viruses, are so small that they cannot be removed by ordinary bacterial filters but require special filtration devices. Gases such as air, containing dustlike suspensions of micro-organisms, can be effectively filtered through thick layers of cotton batting or other materials.

(6) *Osmosis.* The diffusion of a liquid through a semipermeable membrane that separates two miscible solutions is known as osmosis. Although the diffusion may proceed in both directions, the flow of solvent is greater from the more dilute to the more concentrated solution. This diffusion tends to equalize the concentrations of the two solutions. Osmotic pressure is the increased pressure which develops in the more highly concentrated solution. Living cells, including micro-organisms, all have semipermeable cell membranes; hence when they are placed in high sugar or salt concentrations, the osmotic process removes water from them, resulting in inhibition of growth or destruction. Common applications of this principle are the use of high concentrations of sugar to preserve foods, such as jams and jellies, and the soaking of meats in brine. However, these measures are not effective for destroying spores.

b. Chemical.

(1) *General.* Many chemical compounds are used to destroy or inhibit the growth of micro-organisms. Disinfectants are ma-

terials such as germicides and bactericides, which destroy pathogenic micro-organisms. Antiseptics are substances which inhibit the growth and development of micro-organisms, but do not necessarily destroy them. Some chemicals are powerful disinfectants, while others are only inhibitors. Among the common disinfectant and antiseptic preparations are mercuric chloride, silver nitrate, tincture of iodine, chlorine, phenol, cresol, formaldehyde, hydrogen peroxide, alcohol, hypochlorites, and acids or alkalies. The vapors of propylene glycol, triethylene glycol, and ethylene oxide are also effective disinfectants and decontaminants. Proper concentration, temperature, and length of exposure are critical factors in the employment of all these materials.

(2) *Chemotherapeutic agents.* These are chemical compounds, used in the treatment of disease, which affect the causative micro-organism unfavorably without markedly injuring the patient. They may destroy the pathogen, inhibit its growth, or render it more susceptible to the defense mechanisms of the body. Among these substances are the arsphenamines, quinine, and the sulfonamides—sulfanilamide, sulfadiazine, and sulfapyridine—and others.

c. Biological.

(1) *Antibiotics* are substances (chemical compounds) produced by living cells and are selectively antagonistic to other living organisms. (They have the capacity to inhibit the growth of and even to destroy various micro-organisms.) They are usually obtained from micro-organisms, such as bacteria, yeasts, and molds, and sometimes from higher plants. Some antibiotics, such as chloromycetin, originally obtained from a micro-organism, have been synthesized. No one antibiotic is inhibitory to all micro-organisms, but each has a more or less specific inhibitory or growth-preventing action on particular species. Some have proved valuable in the treatment of diseases not responsive to chemotherapeutic drugs, vaccines, or antiserums. Prominent antibiotics include penicillin, streptomycin, chloromycetin, and terramycin.

(2) *Bacteriophages* are viruses which are parasitic to certain bacteria and may destroy them. Like other viruses, bacteriophages multiply only in the presence of living cells. They are widely distributed in nature and are commonly present in the intestines of man and animals, especially those recovering from a bacterial disease. There are various strains or races of bacteriophage, each being specific for certain types or groups of bacteria, but many bacteria, including some of the

more pathogenic, have no known bacteriophage. A very small amount of bacteriophage, when added to an actively growing susceptible bacterial culture, will cause swelling, death, and disintegration of the bacterial cells within a few hours.

13. Infection and Immunity

a. General. Infection occurs when pathogenic micro-organisms invade the tissues, multiply, and produce injury or disease. It represents a conflict between the invader and the living object of attack, in which the host strives to resist the invasion and repel the invading organisms. If they are repelled, the defender suffers no ill effects; if not, infection occurs. Factors which influence the outcome of the struggle are the portals of entry, the virulence and number of organisms, and the defensive powers of the defender—man, animal, or plant. Micro-organisms range from those which produce disease (pathogens) to those which do not produce disease (nonpathogens). Under some circumstances, organisms that are considered nonpathogenic may produce infections; examples are the normal bacteria of the gastrointestinal tract which can produce diseases like peritonitis, colitis, and urinary tract infections. Infectious diseases may or may not be transmissible to other individuals; a contagious disease is an infection which spreads readily from one individual to another by direct or indirect contact (typhoid fever, measles, smallpox, influenza). All contagious diseases are infectious; however, infectious diseases are not necessarily contagious (tetanus, brucellosis, tularemia, malaria).

b. Factors of Infection.

(1) *Virulence.* Virulence refers to the relative infectiousness of an organism or its ability to overcome the defenses of the host. Pathogens range in virulence from those producing mild and temporary disturbances to those causing incapacitation or death. Virulence of certain organisms can be increased by repeated passage from animal to animal. In general, virulence is dependent on two factors—invasiveness and toxicity.

(*a*) *Invasiveness.* Invasiveness is the ability of a micro-organism to enter the body and spread through the tissues. It is the predominant factor in the virulence of some micro-organisms, such as those causing tularemia and blood poisoning.

(*b*) *Toxicity.* Toxicity is the quality of being poisonous, the toxicity of micro-organisms depending on the potency of the toxins they produce. In some microbes invasiveness is of less importance than toxicity, as in the case of the organism causing tetanus.

(2) *Infective dose.* The infective dose denotes the number of organisms necessary to produce infection in an exposed indi-

vidual. It is an extremely variable factor, depending on the micro-organism involved and the species or individual attacked; in some cases, relatively few organisms can produce an infection, while in others large numbers may be repelled by the body.

(3) *Incubation period.* When micro-organisms have been introduced into the host in sufficient amounts to produce disease, an interval of time, known as the incubation period, elapses before symptoms of disease appear. During this time the organisms establish themselves firmly and increase in numbers large enough to cause disease. The incubation period may vary from a few hours to a few weeks, depending on the kind of pathogen, and, during this interval, there may be no sign of disease. At the end of the period, symptoms may appear either gradually or suddenly, and the fully developed disease will become evident. A similar lapse of time occurs between the introduction of nonliving toxins and the appearance of disease symptoms; this may more aptly be termed a latent, rather than an incubation, period.

c. Routes of Infection. The principal portals of entry for micro-organisms into man and animals are through abrasions of the skin, through the mucous membranes of the respiratory, gastrointestinal, and genitourinary tracts, and through the eye. However, it should be recognized that the unbroken skin and mucous membranes are natural defensive barriers which aid in preventing an invasion by pathogenic organisms. Certain organisms require specific routes to infect, while others can invade by several routes. Most respiratory diseases are contracted by the inhalation of droplets of contaminated moisture or dusts. Intestinal infections usually are produced by the ingestion of contaminated food or drink. Some organisms invade by penetration of the skin through hair follicles, sweat gland ducts, or abrasions; other organisms must enter through wounds in order to establish themselves. Tetanus spores, for example, may be swallowed with impunity by man; but if they are introduced into a lacerated wound, tetanus may develop.

d. Symptoms of Infection. In the early stages of disease, a few general symptoms usually appear which indicate that infection has been established. These are fever, malaise, and inflammation.

(1) *Fever.* Warm-blooded animals, including man, normally maintain their body temperatures within quite narrow limits. The occurrence of an infection usually is accomplished by an abnormal rise in temperature, which is called fever. The degree of fever varies in different diseases, but may serve as a rough guide to the severity of the infection; however, the rise in temperature is a protective mechanism, unless it gets so

high that it is harmful to the patient. As a rule, the individual with fever feels quite warm and his skin is likely to be flushed, but the onset of fever may be preceded by a chill which causes him to shiver, sometimes violently. The chill does not necessarily indicate a drop in body temperature, even though there is a cooling sensation of the skin; the temperature of the interior of the body may be abnormaly high. Fever, whether preceded by a chill or not, is usually one of the earliest symptoms of infection and is indicative of illness.

(2) *Malaise.* This is another early set of symptoms of infection in which there is a vague feeling of bodily discomfort, weakness, and exhaustion. It may be accompanied by nausea, dizziness, loss of appetite, and generalized aches; pains in the back, arms, legs, and head may be present. These symptoms may increase in severity as the disease develops or may be overshadowed by other specific symptoms.

(3) *Inflammation.* Inflammation is a reaction of certain body tissues to injury and is characterized by pain, heat, redness, and swelling. Certain kinds of infection are indicated by inflammation of the skin, mucous membranes, or glands, as the body defenses are mobilized to combat the invader and seal off the infection. Some infections are accompanied by a characteristic eruption or rash of the skin, by means of which it is often possible to make an early diagnosis of the particular type of infection that has occurred.

e. Resistance to Infection. The ability of the body to fight off or overcome an infection is known as resistance. The first line of defense is provided by the skin and mucous membranes of the gastrointestinal, respiratory, and genitourinary tracts, and their secretions. These help to prevent entrance of micro-organisms into the deeper tissues, which have little ability to ward off invasion. The second line of defense, of which the lymphatic system is a part, is a cellular one, in which specific migrating cells of the body attack and destroy the invading organisms. The third line of defense is presented by the blood, which contains neutralizing bodies, and the liver and spleen, to which the blood carries organisms and toxins to be destroyed or inactivated.

(1) *The skin and mucous membranes.* The unbroken skin and mucous membranes act as mechanical barriers and are generally impervious to particulate material of bacterial size, some of which may, however, enter the skin through hair follicles and sweat gland ducts. Clean skin is also actively bactericidal to many pathogenic micro-organisms. Sweat acts as a bactericide and also aids in flushing away the germs. The mucous membrane, or mucosa, lines the surface of the canals and

cavities of the body which communicate with the exterior, such as the alimentary canal and its connections, the respiratory tract and its branches, and the genitourinary tract. The mucosa produces a viscid watery secretion, known as mucus, which forms a protective covering and entangles invading micro-organisms. The constant movement, or peristalsis, of the gastrointestinal tract tends to trap micro-organisms in shreds of mucus and thus passes the organisms into the lower bowel and out of the body. Micro-organisms are also entangled by the mucus of the nasal passages and trachea, or windpipe, and swept back to the mouth by coughing or by the action of cilia, which are small hairlike projections lining these surfaces. The mucus of the genitourinary tract acts in a similar manner. Other secretions, such as the acid juices of the stomach, the alkaline ones of the intestines, and the vaginal secretions, either inhibit or destroy micro-organisms, and the saliva and tears protect the body by mechanical flushing.

(2) *Cellular defense.* Should micro-organisms succeed in gaining entrance into deeper tissues, they are attacked by cells known as phagocytes, which appear at the site of invasion within a few minutes and have the ability to ingest and destroy foreign bodies in the blood and other tissues. If the infective agents overwhelm the phagocytes and penetrate more deeply, they may enter the lymph channels and be carried to the lymph nodes where they are engulfed by larger phagocytes. The swelling and tenderness of the lymph nodes are symptoms of this struggle.

(3) *Blood defense.*

(*a*) In addition to the white blood cells, or leucocytes, which are wandering phagocytes, the blood also contains substances called antibodies. These are immune bodies manufactured by the body in response to the introduction of antigens, foreign proteinlike substances, into the tissues. Vaccines are typical antigens which, when injected into the body, cause antibodies to be formed. Micro-organisms and their products, such as toxins, are protein in nature; hence they are antigens. Each antibody is specifically antagonistic to the antigen which stimulated its production and combines with the antigen to neutralize or destroy it. Many kinds of antibodies are produced in the body and are the basis of the active immunity which may be induced naturally or artificially in the body to provide resistance against invading micro-organisms or their poisonous products.

(*b*) Should the invading micro-organisms overcome the cellular and blood defenses, they are carried into the blood stream

and attacked by the large white cells or macrophages in the liver, spleen, and bone marrow, where the blood flow is slower than in other parts of the body, allowing more time and greater opportunity for the macrophages to engulf them.

f. Immunity.

(1) *General.* The ability of the living individual to resist or overcome infection or injury by a pathogenic agent is known as immunity. Relative resistance to infection is dependent upon all the protective barriers, including the skin, mucous membranes, tissue cells, and blood. Resistance due to the presence of certain antibodies in the tissues is the primary factor in determining an individual's immunity. Immunity may be classified into several types.

(2) *Natural immunity.* Certain species of animals, certain races of people, and certain individuals of a given race appear to be born with a resistance to certain infections. Examples of natural immunity are the resistance of man to foot-and-mouth disease, the resistance of dogs to anthrax, and the relative resistance of the negro race to yellow fever.

(3) *Acquired immunity.* This type of immunity may be either naturally or artificially acquired and may be active or passive.

(*a*) *Naturally acquired passive immunity (congenital).* Infants possess immunity to certain infections in the first months of life due to antibodies acquired from the mother. These antibodies soon disappear, and the conferred immunity is then lost. An example of this type of immunity is the resistance of infants to diphtheria during the first year of life.

(*b*) *Naturally acquired active immunity.* This type of immunity is generally the longest lasting of all acquired immunities. It may be the result of recovery from an attack of an infectious disease such as typhoid, diphtheria, or tularemia (rabbit fever); or may be attributed to an earlier, mild, unrecognized infection or to repeated contact with the disease-producing organism in insufficient quantities to produce disease.

(*c*) *Artificially acquired active immunity.* This type of immunity is produced through injection of vaccines of attenuated or dead organisms or injection of toxoids (inactivated toxins) to which the body reacts by forming specific antibodies. Duration of immunity thus acquired varies considerably, depending upon the specific disease and the type of vaccine or toxoid used. Examples of effective vaccines are those of smallpox and typhoid. An example of an effective toxoid is that of diphtheria.

(*d*) *Artificially acquired passive immunity.* This type of immunity is obtained by the injection into the body of antibodies (immune serum) actively produced in another individual or animal in response to either natural infection or injections of specific vaccines. An example of this is the immunity conferred by an injection of tetanus antitoxin. This immunity is relatively short-lived.

g. Treatment Problems. Certain factors may arise in BW attacks that will complicate treatment of casualties. These factors include the probable employment of overwhelming numbers of pathogenic organisms in an attack, the use of drug resistant strains of organisms or organisms of artificially increased virulence, and the dissemination of several agents at the same time to confuse diagnosis and treatment. Another possibility is the combined employment of chemical and biological agents. Other complicating factors might include fatigue, malnutrition, and climatic conditions which would accelerate the course and severity of the resulting disease; and shortages of medical supplies, personnel, and facilities in the event of an overwhelming number of casualties occurring at one time. It will be necessary to consider these factors carefully in preparing for the care and treatment of BW casualties.

Section III. KINDS OF MICRO-ORGANISMS

14. The Bacteria

a. General. Bacteria are microscopic, one-celled, plantlike organisms which have no chlorophyl, the green coloring matter of plants (par. 17). They are widely distributed in nature, being found in soil, air, water, the bodies of living animals and plants, and in dead or decaying organic matter. Unlike viruses and rickettsiae, most bacteria can be grown in culture media in the absence of living cells. Of approximately 2,000 identified species, only about 100 are known to be pathogenic. Most bacteria which infect man are human parasites, but some are primarily parasites of lower animals which are occasionally transmitted to man. Examples of these animal parasites are the bacteria which cause anthrax and tularemia.

b. Form and Structure. Bacteria generally range in size between 0.5 micron and 10 microns across their greatest dimension, but some spirochete forms are much larger. Bacteria are somewhat variable in form but may be classified according to shape into three main groups: the *bacilli* (bacillus, singular)—rod-shaped; *cocci* (coccus, singular)—round or spherical; and the *spirilla* (spirillum, singular)—comma-shaped or spiral organisms. The cocci are further classified into groups based on the manner in which they cling together after cell division. The *diplococci* (diplococcus, singular), dividing in one plane, remain in pairs;

the *streptococci* (streptococcus, singular), dividing in one plane, cling together in chains; and the *staphylococci* (staphylococcus, singular) cling together in irregular grapelike clusters. The rigid spiral bacteria are known as *spirilla,* the flexible spiral-shaped ones are known as *spirochetes,* and the curved or comma-shaped ones are called vibrios.

c. Motility. The round or spherical coccus forms are generally nonmotile. Some of the rod- and spiral-shaped bacteria have the power of independent movement, while others are nonmotile. The motile organisms are propelled by the wavy or screwlike motion of one or more attached flagella—long threadlike filaments—or, in some cases, by the undulation of the flexible body of the organism itself. Examples of motile organisms are the rod-shaped typhoid bacillus, the curved or comma-shaped vibrio of cholera, and the corkscrew-shaped spirochete of syphilis.

d. Pathogenic Types. Bacteria cause many of the common diseases of man and some of those of animals and plants. Representative of the cocci (round) forms are the staphylococci, some of which cause boils and food poisoning; the streptococci, some of which cause scarlet fever and blood poisoning; the gonococci, which cause gonorrhea; and the meningococci, which cause meningitis. The bacilli (rod-shaped bacteria) produce diphtheria, tuberculosis, anthrax, typhoid fever, bacillary dysentery, bubonic plague, tularemia, brucellosis (undulant fever), and glanders. The diseases diphtheria, tetanus, gas gangrene, and botulism are caused principally by the toxins produced by bacilli-type organisms. Cholera is caused by a comma-shaped vibrio form and syphilis by a spiral or corkscrew-shaped spirochete. Examples of diseases of plants caused by bacteria are bacterial wilt of corn and bacterial wilt of cucumbers.

15. The Rickettsiae

a. General. The rickettsial bodies are intracellular parasitic microorganisms that are considered as intermediate between the bacteria and viruses in size. They resemble the bacteria in shape and the viruses in their strict growth requirements for living host cells. Most rickettsiae are primarily parasites of arthropods, such as ticks, lice, fleas, and mites, and are transmitted to man and animals by bites from these vectors. They have a selective affinity for specific types of cells of the human and animal body. As they have not been grown in artificial media, they are considered obligate parasites.

b. Form and Structure. The rickettsiae are from 0.3 to 0.5 micron in length and about 0.3 micron in diameter, and like bacteria may assume either round, paired, or short rod-shaped forms. They are usually capable of being removed by bacterial filters, and are gram-negative, nonmotile, and nonsporulating. They are easily killed by heat, dehy-

dration, and disinfectants. Studies with an electron microscope reveal a homogeneous or slightly granular interior structure resembling that of bacteria.

c. Pathogenicity. The rickettsial diseases of man may be classified, on the basis of certain characteristics, into the following groups—typhus fever, spotted fever, scrub typhus, Q fever, and other miscellaneous diseases. Of these, typhus fevers, spotted fevers, and scrub typhus are clinically similar in that they are accompanied by fever, skin rashes or dark blotches, and central nervous system disturbances. The typhus fevers include classic epidemic (human) typhus, an acute louse-borne infectious disease; murine (endemic) typhus, a milder type of typhus transmitted to man from infected rats by flea bites; and Brill's disease (recrudescent typhus), a relatively mild recurrence of epidemic louse-borne typhus fever in which the rash is frequently absent. The spotted-fever group includes Rocky Mountain spotted fever of the United States, a relatively severe disease transmitted to man by the bite of a tick (animal reservoirs are wild rodents and probably dogs); and other tick-borne or mite-borne diseases, such as Brazilian spotted fever, Choix or pinta fever of Mexico, Tobia fever of Colombia, boutonneuse fever of the Mediterranean area, South African tick-bite fever, North Queensland tick fever, rickettsialpox, maculatum disease of the Gulf Coast of the United States, and possibly some of the tick-borne rickettsioses of India and Russia. Scrub typhus (tsutsugamushi disease), a moderately severe disease, is transmitted to man by the bite of a mite. Q fever is an acute febrile illness which differs from other rickettsial diseases in that it is not transmitted by the bite of an arthopod vector and does not produce a skin rash. This disease is acquired by ingestion or inhalation of contaminated material. Since Q fever can be airborne, it may become the most common of all rickettsial diseases. Other miscellaneous rickettsial diseases of man are trench fever and Bullis or tick fever of Texas. A rickettsial disease of animals is "heartwater" or veldt disease, which is a highly fatal, tick-borne disease of cattle, sheep, and goats in South Africa.

16. The Viruses

a. General. Viruses are complex organic substances which will multiply or increase only in susceptible living host cells. As they are smaller than most bacteria and rickettsiae, they are capable of passing through filters that will retain bacteria and are often termed "filtrable viruses." They are strict or obligate parasites, as without exception none has yet been cultivated in artificial media or in the absence of living cells. They are ultramicroscopic, since they are not visible with the light microscope. Most of them are living micro-organisms, but some, such as the virus of tobacco mosaic diseases, appear to be non-

living, proteinlike substances. Many of them are pathogenic, but some may be harmless parasites.

b. Form and Structure. Viruses range in size from about 0.01 micron to 0.27 micron across their greatest dimension, as determined by filtration, ultramicroscope, electron microscope, and ultracentrifuge studies. Because of their extremely small size, not all viruses have been observed; however, globular, crystalline, square, rectangular, and spherical shapes have been described. It is improbable that all viruses are essentially of the same nature, and it has been suggested that the very small forms, like the crystalline mosaic viruses of tobacco and cucumbers, may be inanimate, while the larger ones are among the smallest living micro-organisms.

c. Pathogenicity. Viruses are responsible for many important diseases of man, animals, and plants. Human diseases caused by viruses include infantile paralysis, rabies, smallpox, yellow fever, encephalitis, mumps, measles, chicken pox, influenza, and the common cold. Important animal diseases produced by viruses are rinderpest and foot-and-mouth of cattle, hog cholera and African swine fever (similar to hog cholera but more acute), distemper and rabies of dogs, and fowl plague and Newcastle disease of fowl. The organism which causes psittacosis, a disease of birds and man, is classed variously as a virus or a rickettsia, or intermediately between them. Typical virus infections of plants are tobacco and cucumber mosaic diseases and curly top disease of sugar beets.

17. The Fungi

a. General. The fungi are unicellular or multicellular members of the plant kingdom not differentiated into roots, stems, or leaves, which do not contain chlorophyl, the green coloring matter. Fungi include molds, mildews, smuts, rusts, mushrooms, toadstools, puffballs, yeasts, and bacteria. From a pathological standpoint the bacteria are the most important of this group, and therefore have been considered separately. Other fungi produce numerous serious plant diseases, but relatively few important diseases of man or animals are attributable to this group of organisms. Even though fungi are destructive to foods, fabrics, and wood, in general they serve a useful purpose in nature by helping to decompose dead organic matter in the forests and in the soil. The products of many fungi are useful in industry and medicine, examples being alcohol, vinegar, ergot, penicillin, and streptomycin.

b. Form and Structure. The cells of fungi, other than bacteria, are usually larger than bacteria, ranging between 3 and 50 microns in size. They are for the most part rod-shaped and arranged end to end in strands or filaments; yeast cells, however, are usually oval and appear singly, or in clumps or long chains. Although molds and yeasts re-

semble bacteria in many respects, they are more complex structurally and physiologically and are considered to be more highly evolved members of the plant kingdom. Some representatives of the fungi which appear to have potential value as BW agents will be discussed separately in this manual.

c. Pathogenicity. Fungal diseases in humans generally are less acute than those produced by other organisms and are for the most part low-grade, chronic infections such as ringworm and "athlete's foot." However, some fungi are capable of producing serious diseases in man, examples of which are actinomycosis, histoplasmosis, and coccidioidomycosis. Actinomycosis is an infectious disease which causes tissue destruction, suppuration, and overgrowth of fibrous tissue; it also occurs in cattle, where it is known as "lumpy jaw." Coccidioidomycosis is an infection which may be localized and relatively mild, or systemic, malignant, and rapidly fatal. Other fungal diseases of man are favus, cryptococcosis, thrush, nocardiosis, blastomycosis, and sporotrichosis. In plants fungi produce many serious diseases, such as brown spot of rice; rice blast; late blight of potato; cereal rusts; Southern blight of sugar beets, white potatoes, and other root crops; smuts; ergot on rye grain; and many others.

18. The Protozoa

a. General. The protozoa are a heterogeneous group of unicellular nucleated organisms and are the smallest, most primitive, and most elemental representatives of the animal kingdom. They are more complex than other micro-organisms in structure and functional activity, locomotion, respiration, ability to procure food, reproduction, excretion, and methods of attachment to other objects. They are widely distributed in nature, being abundant in salt and fresh water and in the upper part of the soil. Some protozoa are parasitic to man and animals.

b. Form and Structure. Protozoa vary greatly in size from a diameter of 1 micron or less to 100 microns or more. The larger ones are visible to the naked eye, but the pathogenic members are usually small, measuring from 1 to 15 microns. They present a great variety of shapes, ranging from irregular and changeable masses of protoplasm, such as the amoeba, to cylindrical, round, or oval forms like the paramecium. The same protozoon may pass through a complex cycle of development which includes several forms, as is the case with the malarial parasite. Most of them are motile, movement being achieved by the use of cilia, flagella, or pseudopodia. Some absorb food directly through the cell wall, others engulf and digest it. A few resemble plants in that they contain chlorophyl, and utilize it in their metabolism to produce their own foods and reserves. Protozoa may reproduce either sexually or asexually.

c. Pathogenicity. Most of the protozoa do not produce disease in man and animals. However, important diseases caused by these organisms include amoebic dystentery, trypanosomiasis or African sleeping sickness, kala-azar, and malaria of man; trypanosome diseases of horses and cattle; and babesiosis (piroplasmosis) of cattle and other domestic mammals. Difficulties of production and transmission would probably make it unlikely that the pathogenic protozoa would be useful as BW agents.

Section IV. THE TOXINS

19. General

Toxins are relatively unstable, poisonous, antigenic substances chemically allied to proteins and are of microbial, plant, or animal origin. They are antigenic since they usually induce the production of specific antitoxins in suitable animals. They have a delayed action, because they require a latent or incubation period, varying with the particular toxins, to develop their poisonous effects. Toxins are elaborated by plants, especially in seeds; by snakes; by insects; and by certain micro-organisms. They should not be confused with other animal or plant poisons, such as alkaloids and glucosides, or with poisonous chemical elements or compounds, which are not considered to fall within the scope of BW. At the present time, most of the toxins seem to offer little promise as BW agents, because of difficulty of production; however, if the chemical structures of some of these compounds are determined and methods for synthesizing them are discovered, their offensive capabilities will be subject to careful scrutiny.

20. Microbial Toxins

Microbial toxins are produced by some bacteria, and presumably by some of the other micro-organisms, such as rickettsiae and viruses. There are two kinds of bacterial toxins—exotoxins and endotoxins. The exotoxins are soluble toxins which diffuse out of the living bacteria, while the endotoxins are liberated only upon the death or disintegration of the bacteria. The exotoxins are much more poisonous than endotoxins but are more easily destroyed by heat and proteolytic enzymes, with the exception of botulinum toxin, which is the only true bacterial exotoxin that is effective when ingested. The exotoxins are detoxified by formaldehyde. The exotoxins are much more efficient in stimulating the production of antitoxins in the animal body than are the endotoxins. Outstanding examples of virulent exotoxins are those of the bacilli causing botulism, diphtheria, gas gangrene, tetanus, and bacillary dysentery; erythrogenic toxin produced by some of the streptococci causes the red skin rash characteristic of scarlet fever. Typical

endotoxins are found in the bacilli of plague, cholera, typhoid, and paratyphoid and in the meningococcus of epidemic meningitis.

21. Zootoxins (Animal Toxins)

Zootoxins are quite numerous, as they occur in poisonous animals in practically every major division from the highest to the lowest. Those particularly dangerous to man are found with few exceptions among the insects, spiders, scorpions, reptiles, and fishes. The chemical behavior and physiological action of the zootoxins are strikingly similar to those of the bacterial exotoxins. Antitoxins have been prepared against a number of these substances, and the antivenins have been employed with considerable success against certain snake venoms. Zootoxins are found in the following groups:

a. Coelenterates. Medusae such as certain jellyfish and Portuguese man-of-war; polyps such as sea anemone and coral polyps.

b. Arthropods. Bees, ticks, spiders, scorpions, centipedes, mosquitoes, and mites.

c. Molluscs. Some shellfish, during spawning season.

d. Reptiles. Lizards (Gila monster, beaded lizard) colubrine snakes (tropical sea snakes, krait, cobra, king cobra, coral snake), and viperine snakes (rattlesnakes, copperhead, water moccasin, fer-de-lance, daboia).

e. Fishes. Sting rays, catfish, other spiny fishes. (A few fish are poisonous when eaten fresh, and in some the poisonous principle appears to exist chiefly in the ovaries, testes, and roe; the eggs of pickerel and gar are toxic, and an active poison is found in eel blood.)

22. Phytotoxins (Plant Toxins)

While many poisonous principles are manufactured by plants, including alkaloids, glucosides, and other toxic substances such as toxicodendrol of poison ivy, very few true toxins are elaborated by them. Prominent examples of phytotoxins are ricin from the castor oil bean, abrin of jequirity seeds, cicutoxin from poison hemlock, and the toxin of the death cup mushroom.

23. Pathogenicity of Toxins

Toxins exert their poisonous actions in a variety of ways. Microorganisms which produce exotoxins may have little or no power of invasion, but the powerful toxins are absorbed into the tissues of the body, causing serious or fatal illnesses, such as botulism, tetanus, gas gangrene, and diphtheria. The exotoxins resemble the alkaloids in that they usually show a selective affinity for certain systems, cells, or tissues of the host, producing symptoms of illness, such as cardiac or respiratory failure, convulsions, blindness, nausea, and fever. The

exotoxin of *Clostridium botulinum* is the most poisonous material known at the present time. The endotoxins are usually rather weak poisons and are liberated only after the dissolution or disintegration of the parent microbial cells. It has been observed that the pathogenic endotoxin-producing organisms generally have greater powers of invasiveness than the exotoxin-producing micro-organisms. Some micro-organisms produce several kinds of exotoxins. The animal or zootoxins in general resemble the bacterial exotoxins in solubility, tissue selectivity, delayed action, and stimulation of host tissues to produce antitoxins. Some snake venoms poison parts of the nervous system of their victim, hence are termed "neurotoxic;" others destroy the red blood cells (hemolysis) or cause the blood to clot in the blood vessels. The phytotoxins have characteristics similar to those of the bacterial exotoxins and zootoxins.

Section V. VECTORS OF DISEASE

24. General

Disease vectors are animal carriers which transfer infective agents from one host to another. They are usually arthropods, but may be other animals, and can be classified into two types—biological and mechanical. Biological vectors are animals in whose bodies the infecting organism develops or multiplies before it can be infective to the recipient animal. Mechanical vectors are those which transmit infective organisms from one host to another but, in themselves, are not essential to the life cycle of the parasite. The mosquitoes which transmit malaria and yellow fever are biological vectors; however, the black horsefly which transmits anthrax and many insects which transmit plant diseases are mechanical vectors. In general, the term "vector" refers to the arthropods, including such insects as mosquitoes, flies, fleas, and lice, and a few acarids, such as mites and ticks. In some cases higher animals such as dogs and cats and even man himself are considered vectors.

25. Arthropod Vectors

The arthropods form one of the great divisions of the animal kingdom, comprising animals with segmented bodies and articulated (jointed) legs and with an exoskeleton; the insects, arachnids, and crustaceans are the most important members. The insects, or hexapods, and the arachnids comprise the groups whose members are significant as vectors or carriers of human, animal, or plant diseases. The insects are distinguished from other arthropods by the separation of the body into three regions—head, thorax, and abdomen—and in having six legs, one pair on each of the three segments of the thorax. Four wings are usually present, also attached to the thorax, and the animals breathe

by air tubes. Most undergo marked changes in form in their development from egg to adult. The insects probably represent the dominant form of animal life on the earth; over 600,000 kinds have been described, which are about 70 percent of the known species of animals. Insects may affect the health of man, animals, and plants by transmitting agents of disease, by invading living tissues, by inoculating poisonous substances, and by acting as pests. Disease-producing microorganisms may be transmitted mechanically by insects and acarids. For example nonbiting flies, gaining access to contaminated material, such as the feces of diseased man or animals, may deposit this material on uncontaminated food and thus serve in the spread of such diseases as typhoid, cholera, and bacillary and amoebic dysentery. Diseases may be carried from infected to noninfected plants in the same manner. Insects and acarids may also transmit disease biologically in that pathogens may increase in number (plague) or undergo developmental change (malaria) within their bodies before they can infect another animal. Some of the prominent arthropod vectors of disease are considered below.

a. Mosquitoes. The virus of epidemic yellow fever is transmitted from man to man by the bite of an insect, the *Aedes aegypti* mosquito; an endemic or "jungle" form of the disease is transmitted by other kinds of mosquitoes to man from other animal hosts of infection (monkeys). Mosquitoes of the genus *Anopheles* are alone responsible for the man-to-man transmission of the protozoan parasite which causes malaria, the most important of arthropod-borne diseases. In this instance, the process is a biological one, as certain necessary developmental changes in the malarial parasite must take place in the body of the anopheline mosquito before the bite of the mosquito can cause the infection in man. Other important mosquito-borne virus diseases are dengue, transmitted from man to man by the bite of *Aedes* mosquitoes; filariasis or elephantiasis, caused by a nematode worm whose vectors are anopheline and culicine mosquitoes; and several types of encephalitis. Rift Valley fever of Africa, an epizootic disease of sheep also affecting man and cattle, is sometimes transmitted by mosquitoes.

b. Flies. The true flies have only two wings, but the word "fly" is often applied in compound names of other insects, such as mayfly, sawfly, and stonefly. Most of the many varieties of flies have sucking mouth parts, but those few which have mouth structures capable of piercing the skin of man or animals include the most important disease vectors. The sucking flies can, however, introduce infection through previously injured body surfaces and are capable of mechanically transferring pathogens to exposed surfaces and food. Typhoid fever, bacillary and amoebic dysentery, and cholera are examples of diseases which may be spread mechanically by nonbiting flies. Yaws, a highly infectious and contagious nonvenereal spirochetal disease resembling syph-

ilis, may be acquired through a cut or abrasion of the skin, either directly by contact with discharges from lesions or indirectly through the agency of nonbiting flies. The nonbiting flies, which include the common housefly, are often termed "filth flies"; it should be emphasized that they easily may carry pathogenic micro-organisms from excrement, sputum, open sores, or putrefying matter to food, milk, and healthy mucous membranes. Some diseases transmitted by biting flies are the dreaded African sleeping sickness, a trypanosomal infection of domestic animals, animals, wild game, and man, whose vector is the tsetse fly; tularemia ("rabbit fever"), a bacterial disease of wild animals and man sometimes transmitted by the horsefly and wood tick; sandfly or pappataci fever, a virus disease affecting man; the leishmanial diseases of man, including kala-azar and oriental sore; and some of the filarial or roundworm diseases of man and animals.

c. Fleas. Fleas are small, wingless, insect parasites of the skin of mammals and birds. Their bodies are flattened laterally, and they have mouth parts for piercing the skin. While different species show preferences for certain hosts, when hungry they will attack any warm-blooded animal, which greatly increases their potential to transmit disease to man. The common rat flea is the ordinary vector of murine typhus, a rickettsial disease of rats and mice, and occasionally bites and infects man with the disease; it is the chief vector of plague from rats and other rodents to man and among rats and mice. Other fleas are known vectors of plague among wild rodents in the western United States.

d. Lice. The lice are sucking, dorso-ventrally flattened, wingless insects, parasitic on the skin of mammals and birds. The body louse (and probably the head louse) is the vector of the rickettsial diseases, epidemic typhus and trench fever. Relapsing fevers of Africa, India, and eastern Europe are louse-borne spirochetal infections affecting the human population.

e. Mites and Ticks. These arthropod vectors are known as acarids and belong to the class *Arachnida,* order *Acarina.* They are usually round or oval forms in which the head, thorax, and abdomen are fused into a saclike, unsegmented body whose surface has a leatherlike appearance. Most of these small animals are merely parasitic skin pests of land vertebrate animals, but a few are important disease vectors. Certain mites transmit scrub typhus fever, also known as tsutsugamushi fever, a rickettsial disease of the Orient. The western wood tick of the United States is known to transmit to man the riskettsia of Rocky Mountain spotted fever, the bacterium of tularemia, and the virus of Colorado tick fever; the wood tick is also suspected of being a carrier of Q fever. The dog tick of the eastern United States can also transmit Rocky Mountain spotted fever. Ticks are responsible for transmitting

the spirochete of relapsing fever. The rickettsiae of Brazilian spotted fever and South African tick-bite fever, and the virus of Russian spring-summer type encephalitis. Texas cattle fever, a protozoan disease, is tick-borne.

26. Other Animal Vectors

Some of the higher animals are biological or mechanical vectors of disease. Rats are host reservoirs and biological vectors of leptospirosis, or Weil's disease, which is carried to man and some of the lower animals when they are exposed to contaminated feces and urine of this rodent pest. Swine are important hosts of trichina, which produces trichinosis in man when he eats inadequately cooked, infected pork products. Mice are vectors of lymphocytic choriomeningitis, which infects man through the upper respiratory tract. Dogs, cats, foxes, and some other animals transmit rabies to man and other animals by biting; birds, particularly the parrot, are carriers of psittacosis (ornithosis). The wild rabbit is an important vector of tularemia, which man can contact by handling the infected carcass of this animal. A good example of a mechanical vector is the buzzard, which can spread anthrax by vomiting infected material after it has consumed the flesh of animals dead of this disease.

27. Vectors of Plant Diseases

Over 100 diseases of plants and trees are known to be transmitted by arthropods, which are carriers for many other infections. In addition, biting and sucking members of the group, not actual carriers of diseases, make it possible for bacterial, viral, and fungal infections to become established by making holes or abrasions in leaves and bark through which these disease organisms may easily make their entrance. Arthropod vectors carrying infectious material in their mouths or on their bodies may transmit infections by inoculation of the host through bites or by deposition of excreta. Examples of such infections are the fire blight of apples, transmitted by bees and other insects; cucurbit wilt disease of cucumbers and other plants, transmitted by striped and spotted cucumber beetles; Dutch elm disease; and chestnut blight. Aphids transmit more than 50 different viruses that cause plant disease, some of which are mosaic of bean, alfalfa, raspberry, soybean, sugar beet, cauliflower, cucumber, sugar cane, and turnip; onion yellow dwarf; sugar beet yellows; potato A, Y, and leaf roll; cabbage blackring; strawberry crinkle and yellow edge; and celery yellow spot. Leafhoppers are next in line as vectors of plant viruses. Curly top of sugar beets, a very serious virus disease, is spread by the beet leafhopper which feeds on the leaves of this plant. Other viruses transmitted by the leafhoppers are the rice stunt (dwarf), cereal mosaic, corn stunt and mosaic, potato and tobacco yellow dwarf, and cotton and tobacco leaf curl. Some other vectors of plant viruses include beetles, grasshoppers,

earwigs, thrips, white flies, and mealybugs. Large animals such as birds and squirrels may also spread plant diseases mechanically by carrying infected material on the surfaces of their bodies.

Section VI. PESTS

28. General

In this text, the meaning of the term "pest" is restricted to certain animals, excluding micro-organisms such as the protozoa, that interfere with the health of other organisms by living on or within them or by associating with them in other injurious ways. Pests are known as parasites when they obtain their food from living host cells. The presence of a large number of parasites on the surface of the host's body producing only mechanical effects is known as infestation; invasion of the tissues of the body of the host by parasites (pathogenic organisms) which produce injury followed by host reaction is known as infection. Living organisms which consume or destroy food, clothing, and forest products are also characterized as pests. Discussion of pests will be limited to examples of classes or individuals which might appear to have potential value in biological warfare under favorable conditions. For this reason serious consideration will not be given to such parasites as flukes, tapeworms, and roundworms. Transmission of diseases by some of these pests has been discussed in paragraphs 24 through 27. Pests are more injurious economically to the plant kingdom than to man and the lower animals, and no crop is free from insect injury. Although many insects are beneficial to agriculture, it has been concluded that the average yearly crop loss in the United States caused by insect pests is about 10 percent and, including costs of control, amounts to nearly 2 billion dollars; the most obvious losses are caused by the feeding of insects, but insect-borne diseases cause great injury. The consequent reduction in the animal and plant food supplies, with resultant increase in cost, has assumed disastrous proportions in the past in countries where there is a narrow margin between supply and demand or where crop diversification is not adequate. Other serious losses result from the destruction of stored food, clothing, and forest products by pests such as rats and insects.

29. Pests Affecting the Animal Kingdom

a. Flukes, Tapeworms, and Roundworms.. Many representatives of these parasitic classes are found in man and animals and include blood, liver, intestinal, and lung flukes; intestinal and tissue tapeworms; and numerous roundworms. Examples of diseases caused by these groups are trichinosis and hookworm. While some produce serious infections, for various reasons they do not appear to have potential BW significance.

b. Arthropods. This group includes most of the pests of man and animals such as centipedes, millipedes, mites, ticks, spiders, and in-

sects. These can interfere with the health of the host by various mechanism—such as by transmission of disease organisms (par. 25), by invading the tissues (mites), by injection of poisons (scorpions, bees), and by annoyance or worry (crawling or buzzing insects). Centipedes inflict painful and sometimes temporarily disabling bites, and millipedes may cause dermatitis; otherwise these pests are of little concern. Aside from their importance as vectors of disease; ticks and mites are mainly annoying pests of the skin of man and animals; the mites may produce severe dermatitis (chiggers) and scabies (scab mite) and may severely weaken birds and chickens (chicken mite) when feeding upon them in large numbers. Mites produce demodectic and sarcoptic mange in animals. Most spiders are harmless, their bite producing only a slight stinging sensation; however, the bite of the black widow spider of the United States has caused serious poisoning in many instances, resulting in several deaths. Insect pests include lice, bedbugs, cockroaches, beetles, bees, ants, bugs, fleas, and numerous kinds of flies. Their importance as vectors of disease has been discussed in paragraphs 24 through 27. In addition, some produce painful irritation and lesions of the skin, nostrils, and eyelids; painful and sometimes serious stings or bites; restlessness; worry; and loss of sleep. Blood-sucking insects, if present in large enough numbers, can cause serious loss of blood in higher animal hosts.

30. Pests Affecting the Plant Kingdom

a. Molluscs. Various snails and slugs are injurious to garden and greenhouse plants by feeding, mostly at night, on leaves, mushrooms, and fruit. A real menace in this group is the giant African snail, *Achatina fulica,* which has recently assumed much importance as a possible invader of this country, having been brought in accidentally on salvaged war equipment from the Pacific Islands, from the Far East, or through the mails. This pest may grow to 6 inches in length, with a shell as large around as an orange. It is very fertile, laying up to 300 eggs in one batch, and will eat almost any vegetable or fruit, even climbing trees to get its food. Only the enactment and strict enforcement of quarantine measures will prevent this pest from getting a foothold in the United States, where it might cause great damage to crops.

b. Nematodes. Eelworms, which are mostly small, whitish, unsegmented roundworms, penetrate tender roots and lead to the formation of root galls and, if present in large enough numbers, may cause severe infestations.

c. Arthropods. The great majority of the pests which afflict the plant kingdom are insects. While it is probable that most insects play a useful role in nature, they are called pests when they become so abundant that their activities interfere directly or indirectly—as in the case of plant crops—with the welfare of man. There are many insects, such

as the Japanese beetle, which, while held in check in their original habitat by environmental conditions and natural enemies, might become serious pests if introduced into another country accidentally or if spread intentionally by an enemy. It might be possible for an enemy to transport and disseminate living insects by aircraft, but if this were not feasible, the insect eggs could be introduced and distributed in the same manner or clandestinely. It should be remembered, however, that for an insect invader to become established, environmental conditions in respect to food supply, moisture, temperature, and natural enemies would have to be favorable. It is not possible in this text to examine all the possibilities, but the potentialities can be imagined if one considers but a few examples of infestations that have occurred in the past or are even now taking place in this country. One of the more destructive insects is the corn earworm (also known as the cotton bollworm or tomato fruitworm), which is worst in the South but is bad in all parts of this country. Fruit insects, such as the codling moth, cause many millions of dollars worth of destruction annually. Sucking insects (such as the scale insects, chinch bug, beet leafhopper, and aphids) produce severe damage to many crop plants and leaf-eating insects (including the grasshopper, the Japanese beetle, the Mexican bean beetle, the boll weevil, and the Colorado potato beetle) destroy a variety of plants. Lumber and shade tree defoliating and bark-eating pests (such as the brown-tail moth, the satin moth, the elm leaf beetle, the European sawfly, the European spruce fly, the Engelmann spruce beetle, and the many pine beetles) have been causing tremendous losses for years. Even lumber that has been cut has to be continually guarded against boring insects such as the lyctus or powder post beetle, termites, and other pests. The grain weevils and other insects destroy tremendous amounts of grain in storage, and clothes moths cost us many millions of dollars annually.

31. Other Pests

While some of the larger animals cause great economic losses, it is not probable that they would have much potential value as BW agents. Examples are such animals as rats, mice, the ground hog, prairie dog, gopher, starling, and crow. It is also possible that the hamster, if allowed to become established in the wild state in this country, would prove to be a most serious pest of plant life because of its tremendous rate of reproduction. The importance of some of these pests as vectors of disease has been discussed in paragraph 26.

Section VII. CHEMICAL ANTICROP COMPOUNDS

32. General

Chemical anticrop compounds, such as contact herbicides, plant growth regulators, and defoliants, are not classed as biological agents

but are included in this group as a matter of convenience, because they might be used to injure or destroy crop plants. Some advantages which they possess over plant pathogens are ease and convenience of production, storage, and dissemination. However, they do not have the ability to spread beyond the original area of dispersion. Herbicides were primarily developed to control or kill weeds, and have been employed for this purpose for half a century. The first ones were inorganic compounds but, because of the high dosages required, they have been largely replaced by organic compounds, including the plant growth regulators. In general the organic compounds are more selective than the inorganic compounds and are less toxic to animal life, partly because of the lower concentrations required. Since the plant growth regulators, and to a lesser extent the contact herbicides, are extremely effective in reducing crop yields or destroying crop plants, their practical value in this respect as compared with that of plant pathogens would have to be assessed on factors such as the variety, importance, and vulnerability of the crops involved and the availability, relative effectiveness, and dissemination possibilities of the particular agent. Defoliants can have military application in controlling vegetation in strategic areas. By defoliating forest areas used for protective purposes by the enemy, air to ground, as well as ground to ground visibility can be improved by exposing enemy positions to friendly ground forces. Friendly fields of fire can also be kept open and clear around our own defensive positions. Defoliants can be used to mark vegetation to denote bomb release lines and rendezvous points and to indicate target direction and position to friendly aircraft.

33. Contact Herbicides

These are compounds which, in sufficiently high concentrations, kill or adversely affect plant life by local injury of the tissue to which the compound is applied. The inorganic forms include compounds such as sodium chlorate, sodium arsenite, arsenic trioxide, borax, calcium cyanamide, sodium and potassium cyanates, ammonium thiocyanate, and ammonium sulfamate. Oils of various kinds have been used as herbicides, including waste, shale, diesel, stove, and crankcase oils, and kerosene. Another group consists of phenolic compounds, particularly "Sinox," 4,6-dinitro-o-cresol, and alkyl-substituted nitrophenols and chlorophenols, which have also been used to fortify oils. Organic compounds useful as herbicides include trichloroacetic acid, pentachlorophenol, and phenylmercuric acetate. It should be emphasized that special care has to be taken in the selection and employment of these herbicides, as their usefulness is dependent on many factors, such as the plant or crop involved, concentration of the agent, and time and conditions of use. Contact herbicides are generally being replaced by the much more po-

tent plant growth regulators, considered in paragraph 34, which are also herbicidal in specific concentrations against certain plants.

34. Plant Growth Regulators

a. Plant growth regulators, sometimes referred to as "plant hormones" or "phytohormones" are synthetic organic compounds which regulate or inhibit plant growth by mechanisms not yet well understood. They have, to a great extent, replaced the earlier contact herbicides and are being intensively investigated in many countries. New compounds of this class are continually being prepared and their actions studied. They are relatively nonspecific and initiate a number of superficially unconnected changes in plants when applied in very low concentrations, while in higher concentrations they may inhibit growth or even produce death. The injury produced is systemic rather than the localized tissue damage produced by the more common inorganic weed killers. Typical members of this group are the substituted phenoxyacetic acids and the carbamates. The first representative of the phenoxyacetic acid group to be developed in this country was 2,4-dichlorophenoxyacetic acid, 2,4–D, which is manufactured to the extent of over 20 million pounds annually in the United States alone. Many proprietary formulations of this compound are now prepared as sodium, ammonium, or alkanolamine salts, or as esters of various alcohols. Of the carbamates, the compounds isopropyl N-phenylcarbamate (IPC) and isopropyl N-(3-chlorophenyl) carbamate appear to have interesting potentialities.

b. Recent introductions in the herbicide field have been 3-(p-chlorophenyl) 1,1-dimethyl urea and maleic hydrazide. The urea compound is a soil sterilant similar in action to some of the low potency herbicides such as trichloroacetic acid or sodium chlorate. The hydrazide is a growth regulator with somewhat less potency than the substituted phenoxyacetic acids when applied to broadleaf plants.

c. Synthesis and investigation of the activities of these plants growth regulators have been in progress for several years. Results indicate that these compounds and possibly others which are presently being tested may have decided offensive possibilities against certain crops. From a logistical standpoint, the plant growth regulators appear to be quite promising as only a very small amount of any one of them is required to produce effective results.

35. Defoliants

Defoliants are compounds which cause trees, shrubs, and other plants to drop their leaves. Although their use on a small scale is practicable, the amounts required for large areas might be considered too great from a logistical standpoint, as they are far less potent than the plant growth regulators. In the process of defoliation, exposed leaves also go through

a process of discoloration. Representative examples of defoliants are ammonium thiocyanate and zinc chloride, both of which can be used as one-third saturated solutions. In addition to causing defoliation, ammonium thiocyanate turns leaves a bright maple-red color and zinc chloride turns them yellowish brown. The defoliation effect might be of value in situations where the defoliant could be sprayed from planes over selected forest areas to denude the trees of leaves and thus deny concealment to enemy installations, materiel, or personnel using forested areas. The discoloration effect, also obtained by spraying from planes, could be used to mark areas of the forest for reconnaissance or as a directional guide for aircraft.

CHAPTER 3
GENERAL PROPERTIES OF BIOLOGICAL WARFARE AGENTS

36. Purpose

The purpose of using BW agents is to produce widespread injury or death in man, domestic animals, plants, food crops, and other essential plant products such as rubber, lumber, and cotton. Under the term "living organisms" are included not only the micro-organisms, but also higher forms of animal life which cause injury either directly or by acting as vectors of disease. The micro-organisms which could be used as BW agents are few, compared with the total number known, but they include the most promising candidates. Any pathogens that could cause diseases having high mortality or morbidity rates might be useful in biological warfare. The toxins are comparatively scarce in number; while they include some of the most poisonous substances known, practical problems exist which will have to be solved before their potential usefulness can be ascertained. Insects and some other animals always have been, and will continue to be, serious pests of the plant kingdom, but their possible value as BW agents remains to be determined. Chemical plant growth regulators appear to have dangerous possibilities as anticrop agents.

37. Properties Peculiar to BW Agents

Most of the BW agents, particularly the pathogenic micro-organisms and toxins, have certain properties not possessed in general by other weapons. They have a delayed action in that a lag or incubation period, often of days, must elapse between the time the victim is exposed to an infectious agent and the time when he comes down with the disease. Identification of microbial agents is difficult and slow as their presence cannot be detected by the unaided senses; it takes hours and usually days for microbial agents to develop in artificial media or in animals and for necessary tests of suspected material to be made. The micro-organisms are living agents in contrast to other agents of warfare. Under favorable conditions pathogenic micro-organisms can reproduce and multiply in the host, so that originally small numbers of pathogens may in time constitute a grave risk to health or perhaps to life. Some contagious pathogens spread from individual to individual and cause epidemics. Most are also quite selective, attacking only certain species of animals or plants. While a given weight of biological agent theoretically may be many times more dangerous than an equal amount of the most effective chemical agent, from a practical standpoint its activity is strictly limited by its ability to survive and main-

tain its virulence under exposure to air, light, heat, cold, dryness, and dissemination methods and its ability to overcome the resistance of the target host. Finally, biological agents lend themselves well to covert use, because the small amounts of material needed are easily concealed, transported, and used in sabotage operations. Because of the relatively small amounts required, their cost should be much less than that of other agents or weapons.

38. Epidemic Spread

A regional outbreak of a contagious disease which attacks many individuals and spreads rapidly is called an epidemic (epizootic in animals and epiphytotic in plants). In each condition there is an unusual increase in the number of cases of the disease in a limited time among a limited population. In nature, the spread of disease occurs from direct contact between individuals, from contact with or ingestion of excreta and contaminated food, from exposure to dusts and mists of infected material (aerosols), and through transmission by animal or insect vectors. Following large-scale dissemination of a biological agent, an *initial outbreak* of disease of epidemic proportions might occur. This might or might not be followed by a secondary or *epidemic spread* of the disease, depending upon its relative contagiousness, the presence or absence of favorable environmental conditions, and other factors. Since epidemics among the human population can be prevented or controlled by sanitation, immunization, quarantine, and treatment, rapidly spreading epidemics are not considered to be likely aftermaths of biological attacks in civilized countries as long as these controlling factors remain at a high level of efficiency. Epizootics among animals have more dangerous possibilities than do epidemics among persons because of the herding and feeding habits of animals; their control or elimination requires extensive use of costly diagnostic and immunological procedures, quarantine where possible, and often the destruction of large numbers of infected animals. Effective measures for preventing or controlling plant epiphytotics and pest infestations are even more deficient, and often impossible, because of the tremendous amounts of manpower and materials required, the vectors involved, and the areas to be covered.

39. Classification

a. Methods. BW agents may be classified subjectively or objectively in several ways, such as kind or type, object of attack, severity of effect produced, viability, virulence, communicability, and tactical or strategical use. Such classifications, for the most part, are not based on hard and fast rules but are relative and often overlapping; they are subject to development of technical knowledge and military doctrine, to such intangible factors as immunity or susceptibility, and to environmental conditions.

b. Type and Kind of Agent. This classification includes the micro-organisms (bacteria, rickettsiae, viruses, protozoa, fungi), the toxins (microbial, zootoxins, and phytotoxins), the pests (of animals, plants, and crops), and the chemical anticrop compounds.

c. Object of Attack. Qualitatively, agents can be classified as antipersonnel (man), antianimal (domestic food and draft animals), and anticrop (plants, food, industrial products). There may be some overlapping between antipersonnel and antianimal agents, in that some agents of one group will be effective against members of the other.

d. Severity. This may be either lethal or nonlethal. Lethal or killing agents can produce death in susceptible animals or plants, but from a practical standpoint death occurs only in a certain percentage of those exposed. The nonlethal pathogenic agents usually do not kill, but may produce infection or disease with prolonged disability among susceptible, exposed individuals. Food and industrial products may be rendered unfit for use by infestation, injury, or contamination.

e. Viability. Viability refers to the ability of BW agents to live and to be infectious after dissemination. The viability of most micro-organisms is highly relative. Since BW agents are living organisms, they are significantly affected by environmental conditions. While most vegetative organisms and toxins may be killed or inactivated by several environmental factors, some of the most delicate agents may survive for prolonged periods if conditions are favorable or if natural reservoirs are established. In general, the sporulating bacteria, such as *Bacillus anthracis* and *Clostridium botulinum*, and the fungous spores are considered to remain viable for greater periods of time than most of the nonsporulating organisms.

f. Virulence. Virulence usually refers to a comparison of the disease-producing abilities of different strains of the same agent, those which do not produce disease being termed "avirulent." Virulence depends on a number of factors, such as those having to do with the particular strain of organisms, its passage through living hosts, and the presence or absence of necessary dietary requirements and environmental factors in culture media or host. Strain selection for increased virulence among known organisms is a distinct probability.

g. Communicability. A communicable disease is one which is transmitted directly or indirectly from one host to another by contact, body excretions, coughing, or sneezing. Such diseases as diphtheria, typhoid fever, mumps, and measles are communicable, while tetanus and botulism are not.

h. Tactical Versus Strategic Use. BW agents, because of their delayed action and for other considerations, would generally be classed as strategic weapons. However, it is possible that in certain situations they

might have definite tactical values. Discussion of this subject is not a matter for consideration in this manual.

40. Requisites of Biological Warfare Agents

a. General. Certain requirements are necessary for organisms or substances to be effective biological warfare agents. It is desirable that they possess additional properties which will enhance their value under conditions of use. The selection of a particular biological warfare agent will be governed not only by the desired effect but also by the agent's properties and the environmental conditions existing in a given situation. It will usually be impossible for any one agent to fulfill all of these conditions; therefore, in making a selection some compromise may have to be made between optimum and minimum requirements.

b. Requirements. The agent should meet the following requirements when used against enemy personnel, his domestic food and draft animals, or plant crops:

(1) It should consistently produce death, disability, or damage.
(2) It should be capable of being produced economically and in militarily adequate quantities from available materials.
(3) It should be stable under production and storage conditions, in munitions, and in transportation.
(4) It should be capable of being disseminated efficiently by existing techniques, equipment, or munitions.
(5) It should be stable after dissemination from a military munition.

c. Desirable Characteristics. The following properties are desirable in agents in certain situations:

(1) Protection against the agent should be available for the using forces in its preparation, storage, and use.
(2) It should be difficult for the enemy to detect the agent or to immunize or otherwise protect himself against it.
(3) The incubation period should be short and predictable by using forces.
(4) The persistence of the agent following dissemination should be short and predictable if the contaminated area is to be occupied by friendly troops before the enemy can send in reserves or replacements.
(5) Under certain conditions, the agent should be capable of producing epidemics.
(6) It should be capable of attacking or infecting the target by more than one portal of entry and of dissemination by various means.
(7) For tactical use it should produce rapid results.
(8) It should complement or supplement attack by other weapons.
(9) It should produce desirable psychological effects.

41. Comparison with Chemical Warfare Agents

Biological and chemical warfare agents are similar in many respects. Except for incendiary agents, they both are antipersonnel, rather than antimateriel, weapons. They may be dispersed in air and travel with the wind in a similar manner and are capable of contaminating terrain, clothing, equipment, food, and water. Man, animals, and plants are susceptible to attack by these agents in varying degree. Unlike projectiles, they can enter any spot where the air can circulate. Variable degrees of protection against both of these agents are afforded by protective masks, protective clothing; and collective protection devices. Biological agents have advantages over chemical agents in that they can multiply after dispersion under favorable environmental conditions, hence smaller and less costly amounts are needed, and sometimes epidemics might be produced. Biological agents have a delayed action of hours or days; some chemical agents act almost immediately and others within a matter of minutes or hours. Field detection of chemical warfare agents is practicable; field detection of BW agents is not possible at the present time, as it is necessary to send suspected material to laboratories for preparation of cultures, examination, and identification, a process which consumes many hours or days. Biological and chemical agents are considered capable of producing similar psychological effects, especially among personnel not familiar with their properties, limitations, and defensive countermeasures.

42. Simulant Agents

Simulant BW agents are micro-organisms or compounds having little or no pathogenicity or toxicity, but otherwise resembling true BW agents in certain characteristics or properties, such as viability, size, food or cultural requirements, growth characteristics, and portals of entry. They are particularly useful in field testing the behavior of munitions, the effect of particle size on penetration of the air passages of animals, and the survival of vegetative and spore-bearing organisms under experimental and environmental conditions. They are also useful in the testing of protective devices and procedures and for training purposes. Examples of microbial simulants are *Serratia marcescens* or *Bacillus prodigiosus,* a vegetative (nonsporulating), rod-shaped bacterium and *Bacillus globigii,* a sporulating, rod-shaped bacterium.

43. Detection and Identification

Detection of a BW agent that has been used in a BW attack is dependent to a great extent upon the observation of unusual circumstances of attack (such as presence of smokes or mists, strange munitions, or unusual vectors) or upon widespread illnesses of persons and animals or widespread damage to crops. Periodic examination of specimens caught on a molecular filter (air intake systems) offers a means of detecting

and identifying a BW agent under certain conditions and in areas where there is a possibility of a BW attack. The process involved in the identification of a BW agent is difficult even under the most favorable conditions. In a BW attack it is probable that unusual disease agents, mixtures of various agents, very high infective dosages, and unusual portals of entry or methods of infection will be employed, all of which will make even more difficult the task of identification of the organisms as well as diagnosis of the disease it produces. Diagnosis of the disease produced by recognition of its characteristic symptoms and its reaction to treatment is of value in helping to identify the BW agent, but this can usually be accomplished only days or weeks after the attack or exposure, because of the incubation period required before symptoms are apparent in the host. Samples of probable BW agents are sent to designated laboratories where they are identified by trained technical personnel.

CHAPTER 4
POSSIBLE ANTIPERSONNEL BW AGENTS

Section I. INTRODUCTION

44. General

The information presented in this chapter, and in the subsequent chapters on antianimal and anticrop agents, is to be found in open scientific literature and therefore is available and, for the most part, known to interested scientific professions of all countries. It is offered in summarized form to acquaint military personnel with the identity and some of the characteristics of certain pathogenic agents which would appear to have potential military applications if pertinent existing difficulties can be surmounted. *Inclusion or omission of specific agents in these discussions is not based on either friendly or enemy military information or intelligence.*

45. Objectives

Antipersonnel BW agents are those which are effective directly against man and are selected on the basis of their ability to cause death or disability through disease. While these agents might be employed against selected individuals, their main value would appear to lie in producing epidemics, with their resultant psychological, crippling, or disheartening effects. The epidemic spread of diseases would be most likely when large numbers of infections could be produced in dense populations subjected to disaster conditions accompanied by shortages in food, clothing, and shelter.

46. Targets

Antipersonnel agents might be used against either the military forces or civilian population, depending on requirements or circumstances, to reduce the effective manpower and thus damage production facilities and combat effectiveness. Areas having large and concentrated populations would furnish the most favorable targets. Other objects of attack might be isolated strongholds or fortified islands.

47. Types

The most promising antipersonnel agents appear to be found among the bacteria, viruses, rickettsiae, and toxins. Most of the fungi are relatively ineffective against man, and the pests can be disregarded. Bacteria are responsible for many of the serious human diseases and offer a wide variety of choice in respect to feasibility of production, stability, viability, portals of entry, casualty-producing effect, transmis-

sion, and methods of dissemination. Included among important bacterial diseases of man are staphylococcal food poisoning, scarlet fever meningococcal meningitis, gonorrhea, diphtheria, tuberculosis, anthrax tetanus, some pneumonias, blood poisoning, botulism, typhoid and paratyphoid fevers, the bacillary dysenteries, plague, cholera, tularemia, brucellosis (undulant fever), glanders, syphilis, yaws, and gas gangrene. The viruses also cause many important human diseases but are difficult to produce in quantity because they have to be grown in living cells. Notable human diseases caused by viruses are influenza, poliomyelitis or infantile paralysis, rabies, smallpox, yellow fever, dengu fever, equine encephalomyelitis, infectious hepatitis, mumps, and measles. The rickettsiae produce fewer diseases than other micro-organisms do; nevertheless, they produce serious diseases, such as Q fever, typhus fever, and the spotted fevers. However, being strict obligate parasites, the rickettsiae present the same difficulties of production as the viruses do and normally are dependent on living vectors for dissemination. The toxins include some of the most poisonous substances known, particularly those produced by the botulinum, tetanus, and diphtheria organisms. Some fungal diseases are coccidioidomycosis and histoplasmosis, while malaria and African sleeping sickness are caused by protozoa.

Section II. BACTERIA

48. Bacillus Anthracis

a. Description. B. anthracis is a rod-shaped, gram-positive, aerobic sporulating micro-organism, the spores constituting the usual infective form.

b. Disease Produced. Anthrax may appear in three forms in man—cutaneous, pulmonary, and intestinal. The cutaneous or skin form is also referred to as malignant pustule, occurring most frequently upon the hands and forearms of persons working with infected livestock, and is characterized by carbuncles and swelling at the site of infection. Sometimes this local infection will develop into systemic infection. The pulmonary form, known also as wool-sorters disease, is an infection of the lungs contracted by inhalation of the spores; it occurs mainly among workers handling infected hides, wool, and furs. The intestinal form, which is rare in man, is contracted by ingestion of insufficiently cooked meat of infected animals.

c. Sources of Infection. Cattle, sheep, and horses are the chief animal hosts, but other animals may be infected. The disease may be contracted by the handling of contaminated hair, wool, hides, flesh, blood, and excreta of infected animals, and manufactured products such as bone meal.

d. Mode of Transmission. Transmission is made through scratches or

abrasions of the skin, wounds, inhalation of spores, eating of uncooked infected meat, or by flies.

e. Incubation Period. Incubation is from 1 to 7 days. It is usually less than 4 days and may be less than 24 hours in pulmonary cases.

f. Susceptibility and Resistance. Presumably, all human populations are susceptible. Recovery from an attack of the disease may be followed by immunity.

g. Prevalence. Anthrax is rare in man and is associated only with animal infections or handling of infected hides and furs.

h. Mortality. In man, the mortality of untreated cutaneous anthrax ranges up to 25 percent; in pulmonary cases, it is almost 100 percent, while the rare intestinal cases usually are fatal.

i. Immunization. Artificial active immunization measures have been developed and are presently being evaluated for man. Antianthrax serum confers some passive immunity.

j. Treatment. Cutaneous anthrax can be treated effectively with some antibiotics, including penicillin, aureomycin, terramycin, and chloromycetin; sulfadiazine; and immune serum. Similar treatment for respiratory and intestinal infections may be useful in the very early stages, particularly if combined with the use of immune serum, but is of uncertain value after the disease is well established.

k. Epidemicity. The disease is not epidemic in man. Control of the disease is accomplished by disposal of carcasses (burning or deep burial) and by decontamination of animal products.

l. Stability. The spores are very stable and may remain alive for many years in soil and water. They will resist sunlight for several days. Steam under pressure or exposure to dry heat above 284° F. for an hour are necessary to kill spores. Effective decontamination also can be accomplished by boiling contaminated articles in water for 30 minutes or by using some of the common disinfectants. Iodine and chlorine are most effective in destroying spores and vegetative cells.

49. Shigella Dysenteriae

a. Description. Sh. dysenteriae is a rod-shaped, gram-negative, nonmotile, nonsporulating bacterium.

b. Disease Produced. Bacillary dysentery, an infectious disease of man, is characterized by mild or severe irritation of the lower gastrointestinal tract; it is usually accompanied by fever, abdominal pain, diarrhea, weakness or prostration, and ulceration of the mucous membranes of the intestine.

c. Source of Infection. Feces of infected human patients and carriers are sources of infection.

d. Mode of Transmission. Transmission is made by ingestion of contaminated food, water, or milk; by hand-to-mouth transfer of contaminated material soiled with feces of a patient or carrier; or by flies.

e. Incubation Period. Incubation is from 1 to 7 days, usually less than 4 days.

f. Susceptibility and Resistance. Most persons are susceptible, but the disease is more common and severe in children than in adults. Recovery from disease is followed by a relative, transitory immunity. Washing, ordinary sterilization methods and use of some of the common disinfectants are effective decontamination measures.

g. Prevalence. The disease is endemic throughout the world, and epidemics or sporadic outbreaks occur where sanitation is lacking or inadequately applied or enforced, particularly in relation to sewage disposal, food handling and preparation, and infant hygiene. Outbreaks are most common in summer months and occur frequently in large institutions.

h. Mortality. Mortality is variable, ranging from 2 to 20 percent in untreated cases, depending on the particular strain of organism.

i. Immunization. At the present time immunization methods for man are unsatisfactory, but there appear to be promising vaccines under development.

j. Treatment. Beneficial results may be obtained from treatment with sulfadiazine, terramycin, chloromycetin, and aureomycin.

k. Epidemicity. The disease is highly contagious, particularly under unsanitary conditions. Control measures include rigid sanitation (careful handling of excreta and adequate sewage disposal) and fly control.

l. Stability. The dysentery organisms remain viable for considerable periods in water, ice, and mucous discharges but are readily killed by sunlight. Sterilization by steam and common disinfectants are effective decontaminants.

50. Brucella Group

a. Description. In this group are included three closely related organisms, *Brucella melitensis, Brucella abortus,* and *Brucella suis.* All are nonmotile, nonsporulating, gram-negative, rod-shaped bacilli.

b. Disease Produced. Brucellosis or undulant fever in man, a general infection, is characterized by irregular prolonged fever, profuse sweating, chills, pain in joints and muscles, and fatigue. The illness lasts for months, sometimes for years, and may be caused by any one of the three related organisms. *Br. abortus* is a parasite of milk cows, producing contagious abortion in cattle; the organism has also been reported in mares, sheep, rabbits, and guinea pigs. *Br. melitensis* is primarily a

strict parasite of goats and sheep; *Br. suis* is a parasite of swine. *Br. melitensis* and *Br. suis* are more virulent for man than *Br. abortus*.

c. Sources of Infection. Brucella organisms are found in the tissues, milk, and dairy products of infected goats, cattle, and swine.

d. Mode of Transmission. These diseases are transmitted to man by ingestion of contaminated milk and other dairy products, pickled meats, and uncooked foods and water contaminated by excretions of infected animals; and by direct contact with infected animals or animal products. Infection has also occurred by inhalation and by accidental inoculation among laboratory workers.

e. Incubation Period. Incubation is from 6 to 60 days or more, averaging 14 days.

f. Susceptibility and Resistance. Most individuals have some degree of resistance or acquired partial immunity to the abortus strains of the organism, probably from ingestion of small doses. Susceptibility of man to *Br. melitensis* infection ranges from 50 to 80 percent, although it may range from 75 to 80 percent; susceptibility to *Br. suis* appears to be approximately equal to that of *Br. melitensis;* susceptibility to *Br. abortus* appears to be not more than 50 percent.

g. Prevalence. Brucellosis is prevalent in most areas where cattle, goats, and swine are raised. Infection of man occurs more often in males than in females, particularly in persons working with cows, hogs, goats, and dairy products, or among those using unpasteurized milk of cows or goats.

h. Mortality. Mortality of untreated infections is said to average 2 to 3 percent with *Br. abortus* and 3 to 6 percent with *Br. suis* and *Br. melitensis.*

i. Immunization. Immunization methods are unsatisfactory for man. Immunization of calves is effective as a control measure.

j. Treatment. The course of the disease may be shortened by appropriate treatment with antibiotics, particularly by a combination of streptomycin and terramycin. However, some cases are resistant to all forms of therapy.

k. Epidemicity. The disease is not communicable from man to man. Epidemics could result from wide-scale consumption of contaminated, unpasteurized dairy products.

l. Stability. Brucella organisms will remain alive for weeks in water, unpasteurized dairy products, and soil and are very resistant to low temperatures. Contaminated materials are easily sterilized or disinfected by common methods. Pasteurization is effective for contaminated dairy products.

51. Vibrio Comma

a. Description. This micro-organism is a short, slightly bent, motile, gram-negative, nonsporulating rod.

b. Disease produced. Cholera, an acute infectious gastrointestinal disease of man, is characterized by sudden onset with nausea, vomiting, profuse watery diarrhea with "rice-water" appearance, rapid loss of body fluids, toxemia, and frequent collapse.

c. Source of Infection. Feces and vomitus of patients, feces of convalescents, and temporary carriers are sources of infection.

d. Mode of Transmission. Transmission is made through direct or indirect fecal contamination of water or foods, by soiled hands or utensils, or by flies.

e. Incubation Period. Incubation is from 1 to 5 days, usually 3 days.

f. Susceptibility and Resistance. All populations are susceptible, while natural resistance to infection is variable. Recovery from an attack is followed by a temporary immunity which may furnish some protection for years.

g. Prevalence. Endemic centers exist in India and southeastern Asia, from which the disease may spread along human communication lines to more remote countries and cause epidemics. It is normally absent from the Western Hemisphere.

h. Mortality. Mortality ranges from about 3 to 30 percent in treated cases to 50 percent in untreated cases.

i. Immunization. Artificial immunization with vaccines is of variable degree and uncertain duration (6 to 12 months). Acquired immunity lasts for many years.

j. Treatment. The first consideration in the treatment of cholera is to replenish fluid and mineral losses of the body. Drug therapy has little or no effect upon the clinical course of the disease. However, chloromycetin, aureomycin, and terramycin, given by mouth, cause rapid disappearance of the vibrio organisms, thus reducing the spread of the disease.

k. Epidemicity. Epidemicity is very high under unsanitary conditions, especially those concerned with water supplies, foods, and fly control.

l. Stability. The organism is easily killed by drying. It is not viable in pure water, but will survive up to 24 hours in sewage, and as long as 6 weeks in certain types of relatively impure water containing salts and organic matter. It can withstand freezing for 3 to 4 days. It is readily killed by dry heat at 212° F., by steam and boiling, by short exposure to ordinary disinfectants, and by chlorination of water.

52. Corynebacterium Diphtheriae

a. Description. This bacterium (a slender, often slightly curved rod) is gram-positive, nonmotile, nonsporulating, and nonacidfast. It varies in size from 2 to 7 microns in length and from 0.5 to 1 micron in diameter. The rodlike forms are usually arranged in palisades and often exhibit club-shaped terminal swellings. They stain irregularly, displaying bars or granules as a result of irregular distribution of protoplasm within the cell. Although the organism is normally aerobic, it is often capable of anaerobic cultivation. It produces a highly potent exotoxin, both in the body and in culture.

b. Disease Produced. Diphtheria, an acute febrile disease, is generally characterized by local infection, usually involving the air passages. The systemic manifestations are due to absorption of the soluble toxin into the blood stream. The bacteria multiply rapidly in the tonsils, nose, and throat, where grayish membranes patches appear on the mucous membranes, causing sore throat and stoppage of air passages. Skin and wound infections are not uncommon in tropical and subtropical climates. Early diphtheria is usually a surprisingly mild disease unless symptoms of obstruction develop. During the first few days of infection, the throat is not particularly sore, there is only slight fever, and there are no severe constitutional symptoms. This lack of obvious symptoms is characteristic of diphtheria in the adult and is especially dangerous when infection occurs in the nasal passages, because the infection is not recognized or treatment is not begun until sufficient exotoxin has been absorbed to cause irreparable damage to other parts of the body.

c. Source of Infection. Discharges from the nose and throat of infected persons and healthy carriers or from skin lesions are sources of infection.

d. Mode of Transmission. The disease is contracted by direct contact with patients or carriers, by droplet infection, or through articles freshly contaminated with nose and throat discharges of infected individuals.

e. Incubation Period. The incubation period is usually from 2 to 5 days but occasionally may be longer.

f. Susceptibility and Resistance. Susceptibility is general in the absence of previous contact with the organism or its toxin. In the past there was a very high percentage of immunity in the adult population because of repeated contact with usually unrecognized sources of infection. Because of the current widespread practice of diphtheria vaccination during infancy, there is less frequent opportunity for natural exposure to doses sufficient to produce immunity. Therefore, the adult population is now more susceptible to the disease than in the past. This susceptibility can be accurately measured by means of the Schick test. Recovery from the disease does not necessarily result in immunity.

g. Prevalence. The disease is endemic and epidemic around the world. It is more common in temperate zones than elsewhere and during the fall and winter. Age distribution of cases and deaths depends largely upon childhood immunization practices.

h. Mortality. Fatality rate is variable, depending upon the virulence of the infecting strain; among untreated cases it may range from 10 to 50 percent. In cases receiving antitoxin treatment, this rate is lowered to 2 to 8 percent.

i. Immunization. Diphtheria toxoid is extremely effective. Permanent immunity may be maintained by means of booster inoculations at regular intervals.

j. Treatment. Diphtheria antitoxin is effective when given promptly and in adequate dosage. Penicillin as a supplementary treatment suppresses secondary invaders, shortens the period of illness, and reduces the number of convalescent carriers.

k. Epidemicity. Epidemicity is high, depending on the immunity status of the population and degree of exposure to the disease. A large proportion of the cases occur in children under 5 years of age.

l. Stability. The diphtheria organism is more resistant to light, drying, and freezing than are most nonsporulating bacilli, remaining viable for a long time in air and dust. It is capable of surviving many hours on a cotton swab and has been cultured from dried bits of diphtheritic pseudomembrane after 14 weeks. It is destroyed by ordinary antiseptics and by being boiled for 1 minute or by being heated to 136° F. for 10 minutes.

53. Bacterium Tularense (Pasteurella Tularensis)

a. Description. This is a small, aerobic, gram-negative cocco-bacillus, often varying in size and shape. It is nonmotile and nonsporulating.

b. Disease Produced. Tularemia is also known as rabbit fever and deer fly fever. It is a fatal septicemic (blood poisoning) disease of wild rodents, accidentally communicable to man, in whom it is characterized by sudden onset with chills, fever, and prostration and by a tendency to pneumonic complications. In man it is an acute, severe, weakening disease, later becoming chronic, and may be accompanied by enlargement of the regional lymph glands with or without a lesion at the site of infection, or by typhoidlike symptoms with no local lesion or enlargement of the local lymph glands.

c. Sources of Infection. Wild rabbits or hares, deer flies, ticks, and many other animals (including the woodchuck, coyote, oppossum, tree squirrel, skunk, cat, deer, fox, hog, sage hen, and some snakes) are sources of infection.

d. Mode of Transmission. Transmission is made by infection through the skin, eyes, or lungs from handling infected animals, as in skinning or dressing the animals or performing autopsies; by bites of infected flies and ticks; by eating insufficiently cooked rabbit meat; or by drinking contaminated water. Laboratory infections are not infrequent.

e. Incubation Period. Incubation is from 1 to 10 days, usually about 3 days.

f. Susceptibility and Resistance. All ages are susceptible, and recovery from an attack is followed by permanent immunity. The infectivity rate is from 90 to 100 percent.

g. Prevalence. The disease is present throughout North America and in many parts of continental Europe and Japan. It occurs in every month of the year in the United States.

h. Mortality. Untreated cases have a death rate of 4 to 8 percent averaging 5 percent.

i. Immunization. Vaccination greatly reduces the severity of the disease and may prevent infection in some cases.

j. Treatment. The antibiotics, particularly streptomycin, aureomycin, and chloromycetin, are effective.

k. Epidemicity. The disease is essentially sporadic, but may be epidemic when modes of transmission (*d* above) are prevalent. It is not transmitted directly from man to man.

l. Stability. The organism remains viable for weeks in water, soil, carcasses, and hides, and for years in frozen rabbit meat. It is resistant for months to temperatures of freezing and below. It is rather easily killed by heat at 113° F. or above for a few minutes and by 0.5 percent phenol in 15 minutes.

54. Pasteurella Pestis

a. Description. Pasteurella pestis is a rod-shaped, nonmotile, nonsporulating, gram-negative, aerobic bacterium.

b. Disease Produced. Plague, or black death, occurs as three clinical types in man—bubonic, pneumonic, and septicemic. Another type of plague, sylvatic plague, is an infectious disease of wild rodents; it is transmissible to man by flea bites. In general, plague is characterized by a rapid clinical course with high fever, extreme weakness, glandular swelling, pneumonia, and/or hemorrhages in the skin and mucous membranes.

(1) *Bubonic plague,* the most common, is transmitted to man by the bite of an infected flea, the disease being perpetuated by the rat-flea-rat transmission cycle. The flea bites are usually on the lower extremities where the bacilli spread rapidly

through the lymphatic system, enlarging the lymph nodes (buboes) in the groin. The bacilli escape from the nodes, invade the blood stream, and produce a generalized infection. Other parts of the body that are affected are the spleen, lungs, and meninges.

(2) *Pneumonic plague,* transmitted by inhalation, spreads rapidly until the entire lung is involved in a hemorrhagic, pneumonic process. The disease is usually fatal, the patient dying of suffocation and/or general toxemia.

(3) *Septicemic plague* occurs as the result of gross invasion of the blood stream by plague bacilli, which cause small hemorrhages in the skin and mucous membranes. Death occurs before buboes or pulmonic manifestations appear.

(4) *Sylvatic plague,* transmitted by wild rodent fleas, is somewhat different from the plague transmitted by the rat flea (bubonic). The flea bites usually occur in the upper extremities and buboes originate in the armpits rather than in the groin. It frequently changes over to the pneumonic type.

c. Sources of Infection. Infected rodents and human patients with pneumonic plague are sources of infection. The primary source of the disease is plague of wild rodents, including the ground squirrel, pack rats, and harvest mice of the United States, and various species of wild rodents in other parts of the world. Infection may reach man from these sources or more often through the medium of the domestic rat.

d. Mode of Transmission. Pneumonic plague is usually transmitted directly from man to man by droplet infection. Bubonic plague is generally transmitted to man by the bites of fleas from infected rats and other rodents.

e. Incubation Period. Incubation is from 1 to 7 days for pneumonic plague, 4 to 7 days for bubonic plague.

f. Susceptibility and Resistance. Susceptibility is general, particularly to the pneumonic form. Recovery is followed by temporary, relative immunity.

g. Prevalence. The disease is rare in North America and island possessions of the United States. Occasional cases of the bubonic type occur west of the Mississippi River from bites of fleas from infected wild rodents. The disease has foci of infection in various parts of the world, particularly in Asia.

h. Mortality. Untreated bubonic plague has a mortality of 30 to 60 percent, while untreated pneumonic plague kills from 90 to 100 percent of its victims.

i. Immunization. Antiplague serum produces an artificial passive immunity of 2 weeks' duration. Active immunization with killed bacterial vaccines is protective for some months when administered in 2 or 3 doses at weekly intervals, repeated stimulating doses being necessary. According to some authorities, vaccines prepared from living avirulent strains confer a better and longer immunity than do vaccines from other sources.

j. Treatment. Prompt treatment with sulfonamides and streptomycin (chloromycetin and aureomycin may be used if resistance to streptomycin develops) combined with serum therapy is essential and is effective if used early. Supportive treatment for pneumonic and septicemic forms is required. These measures shorten the duration of the disease and reduce its mortality.

k. Epidemicity. Bubonic plague is not directly communicable from person to person, but pneumonic plague is intensely communicable during the acute period. Strict area quarantine and sanitation, in addition to other measures such as rat flea extermination (DDT), are essential to control outbreaks.

l. Stability. The organism probably will remain viable in water from 2 to 30 days and in moist meal and grain for about 2 weeks. At near freezing temperatures, it will remain alive from months to years but is killed by 15 minutes' exposure to 130° F. It also remains viable for some time in dry sputum, flea feces, and buried bodies but is killed by 3 to 5 hours' exposure to sunlight. Decontamination is effected by boiling, use of dry heat above 130° F. or steam, and treatment with lysol or chloride of lime.

55. Malleomyces Mallei

a. Description. This organism is a slender, nonmotile, nonsporulating, gram-negative, aerobic, rod-shaped bacterium.

b. Disease Produced. Glanders, an infection occasionally communicated to man, is characterized by nodular, ulcerative lesions of the skin, mucous membranes, and viscera. It is an acute or chronic disease mainly of horses, mules, and asses, communicable to dogs, goats, and sheep. The acute form is limited to the nasal mucosa and upper respiratory tract; the chronic form, called farcy, is characterized by farcy buds, ulcers, and pus-forming lesions in the joints and muscles.

c. Sources of Infection. Infected horses, mules, and asses are sources of infection.

d. Mode of Transmission. Transmission is usually made by droplet infection (inhalation) or through breaks in the skin; it is sometimes made through the gastrointestinal tract.

e. Incubation Period. Incubation is from 3 to 5 days.

f. Susceptibility and Resistance. Man is highly susceptible to glanders, and the disease does not confer immunity against a second attack.

g. Prevalence. Glanders is prevalent among horses, mules, and asses in the Balkans, Russia, Southeastern Asia, and India and is uncommon elsewhere.

h. Mortality. In untreated cases, the acute form has a mortality of nearly 100 percent, while mortality of the chronic form ranges from 50 to 70 percent.

i. Immunization. Satisfactory immunization procedures have not been developed.

j. Treatment. Prompt and radical surgery is the most effective treatment for the chronic form. Sulfadiazine and streptomycin are reported to be effective. The value of newer antibiotic drugs is not yet clearly established.

k. Epidemicity. Although the disease is contagious, epidemic spread in man is improbable.

l. Stability. The organism resists drying for 2 or 3 weeks but is killed by direct sunlight in a few hours. It may remain alive in decaying matter for 2 to 3 weeks. It is easily killed by the common disinfectants and by being heated at 130° F. for 10 minutes.

56. Malleomyces Pseudomallei

a. Description. This bacterium is motile, nonsporulating, gram-negative, aerobic, rod-shaped, and small (1 to 2 microns long and 0.5 micron wide). It is often marked by bipolar staining. It closely resembles *Malleomyces mallei.*

b. Disease Produced. Melioidosis, also known as Whitmore's disease, is a glanderslike disease primarily of rodents but occasionally found in man. It tends to run a more rapid course than glanders does and in man is almost always acute and rapidly fatal, death occurring usually in 3 to 4 weeks, often within 10 days. Recently, reports of chronic infections involving lungs and lymph glands, bones, joints, and legs have appeared. The disease is characterized by sudden onset with severe chills, high fever, rapid prostration, headache, muscle and joint pains, cough, labored breathing, nausea, and vomiting. In a short time, numerous small abscesses form in the skin, bones, lymph nodes, lungs, and other internal organs.

c. Source of Infection. Probable sources of infection are food or other materials contaminated with rodent excreta and possibly rat fleas.

d. Mode of Transmission. Transmission takes place apparently by ingestion of food contaminated with excreta of infected rats and by rat flea bites.

e. Incubation Period. Although not accurately known, the incubation period is probably only a few days.

f. Susceptibility and Resistance. Susceptibility is general but the organism apparently is not extremely infective under natural conditions, considering the low prevalence of human disease in endemic areas. However, man appears to have little or no resistance to it once infection is established.

g. Prevalence. Cases of the disease have been found chiefly in the Malay States, Indochina, and Ceylon. They have also been reported in Guam and the Philippine Islands and recently in the United States.

h. Mortality. Acute melioidosis is usually fatal.

i. Immunization. No vaccine has been developed. Little is known of any immunity acquired through infection.

j. Treatment. Chloromycetin alone or in combination with terramycin or aureomycin has been used with marked success. Sulfadiazine is also effective in the acute stage.

k. Epidemicity. The disease is normally not contagious. Spread by droplet infection might occur in a cold climate, which is more suitable to this type of transmission.

l. Stability. The organism is extremely resistant to drying and may survive a month or more in dried soil, in excreta, and in water. It is easily killed in 10 minutes by 1.0 percent phenol or 0.5 percent formalin and by moist heat at 133° F.

57. Salmonella Typhosa

a. Description. This organism is a rod-shaped, motile, nonsporulating, gram-negative bacterium. It is also known as *S. typhi.*

b. Disease produced. Typhoid fever is a systemic infection characterized by continued fever, lymphoid tissue involvement, ulceration of the intestines, enlargement of the spleen, rose-colored spots on the skin, diarrhea, and constitutional disturbances.

c. Source of Infection. Feces and urine of infected individuals and carriers are sources of infection.

d. Mode of Transmission. Transfer of organisms is made through the alimentary tract by direct or indirect contact with a typhoid patient or a chronic carrier; by consumption of contaminated water, food, milk, or shellfish; and by flies.

e. Incubation Period. Incubation is from 3 to 38 days, usually 7 to 14 days.

f. Susceptibility and Resistance. Susceptibility is general, except that some adults have an acquired immunity from unrecognized infection. Recovery usually is followed by permanent immunity.

g. Prevalence. The disease is widespread throughout the world. Once endemic and epidemic in most large cities of North America, it has been steadily falling in incidence, particularly in areas supplied with safe water and pasteurized milk, and where modern sewage disposal facilities are used. It is still endemic in some rural areas of the United States, usually as sporadic cases or in small carrier or contact epidemics.

h. Mortality. The mortality in untreated cases ranges from 0 to 10 percent.

i. Immunization. Inoculation with typhoid vaccine produces an artificial active immunity of about 2 years' duration. High protection lasting for about a year can be maintained by an annual booster injection of vaccine.

j. Treatment. Prompt use of appropriate antibiotics (chloromycetin, aureomycin) shortens the period of communicability and rapidly cures the disease.

k. Epidemicity. Epidemicity is high in the presence of carriers; in the absence of sanitary control for water, food, and milk supplies; and where individuals are not protected by immunization.

l. Stability. The organism remains viable for 2 to 3 weeks in water, up to 3 months in ice and snow, and for 1 to 2 months in fecal material. Pasteurization, exposure to 132° F. for 20 minutes, exposure to 5 percent phenol or 1:500 bichloride of mercury for 5 minutes, cooking, and boiling are effective decontamination measures.

58. Salmonella Paratyphi and Salmonella Schottmuelleri

a. Description. These organisms are short, plump, rod-shaped, motile, nonsporulating, gram-negative bacteria. *S. paratyphi* is known as type A of the group; *S. schottmuelleri* is known as *S. paratyphi B.*

b. Disease Produced. Paratyphoid fever (an acute, febrile, generalized infection) is very similar to typhoid fever (indistinguishable clinically), but its symptoms are usually milder. It is characterized by continued fever, severe diarrhea, and abdominal pain, with involvement of the lymphoid tissues of the intestines, enlargement of the spleen, and sometimes rose-colored spots on the trunk. *S. schottmuelleri* (type B) is responsible for more cases of the disease than type A and may also produce gastroenteritis. [*Salmonella hirschfeldii (S. paratyphi C)* may also produce paratyphoid fever.]

c. Source of Infection. Contaminated feces and urine of patients and carriers are sources of infection.

d. Mode of Transmission. Transfer of organisms is the same as for typhoid.

e. Incubation Period. Incubation is variable, from 1 to 10 days, depending on strain of organism but averaging less than a week.

f. Susceptibility and Resistance. Susceptibility is general, and recovery is followed by permanent immunity.

g. Prevalence. The disease is world-wide, but incidence has declined with that of typhoid. Outbreaks are sporadic or limited and are due to contact or to consumption of contaminated foods such as milk or water. There are probably many unrecognized cases. Paratyphoid fever caused by *S. hirschfeldii* has been found relatively frequent in parts of Asia, Africa, and southeast Europe but is almost unknown in the United States.

h. Mortality. Fatalities are low, perhaps between 1 and 2 percent.

i. Immunization. Paratyphoid vaccine for types A and B is usually incorporated with typhoid vaccine. See paragraph 57*i* for immunity produced.

j. Treatment. Chemotherapy with "sulfa" drugs and use of antibiotics, such as chloromycetin, aureomycin, and streptomycin, shorten the period of communicability and hasten cure of the disease.

k. Epidemicity. The epidemicity is similar to that for typhoid, depending on presence of carriers; inadequate sanitary controls for water, food, and milk supplies; and absence of immunization.

l. Stability. Stability is the same as for *S. typhosa* (par. 57*l*). Decontamination measures include chlorination, pasteurization, boiling, and cooking.

59. Salmonella Typhimurium

a. Description. This bacterium is a short plump rod which occurs singly and measures 0.5 micron in width and from 1 to 1.5 microns in length. It is gram-negative, nonsporulating, and motile.

b. Disease Produced. Salmonella food poisoning (gastroenteritis) is most frequently caused by *S. typhimurium* in man. The onset of the infection is nearly always sudden, characterized by headache, chills, and usually by abdominal pains. This is followed by nausea, vomiting, and severe diarrhea with a rise in temperature and prostration. Recovery is usually complete within 2 to 4 days.

c. Source of Infection. The sources of infection are usually rodents, especially rats and mice, and human carriers who handle food, eggs, and meat from diseased animals.

d. Mode of Transmission. The disease is usually obtained by the ingestion of contaminated food (particularly meat), water, or milk. It may also be obtained by direct contact with infected persons or carriers, by direct contact with articles contaminated by discharges (feces, urine, and vomitus) of infected persons or carriers, or from flies.

e. Incubation Period. Food poisoning occurs usually after an incubation period ranging from 6 to 24 hours but seldom after more than 48 hours. The short interval suggests that large numbers of the organisms are usually ingested.

f. Susceptibility and Resistance. Susceptibility is general. The disease is more severe in infants and young children than in adults. Natural immunity is believed to exist in some persons, while acquired immunity is usually permanent after recovery from the disease. (The bacterium is primarily pathogenic for animals; in mice it produces a typhoid-like disease with high mortality.)

g. Prevalence. The disease is widely distributed geographically and occurs in almost all warm blooded animals.

h. Mortality. Fatalities range from 1 to 2 percent in epidemics.

i. Immunization. Vaccination is not practical.

j. Treatment. Treatment is mainly physiologic. A saline purge is indicated if the infected food has not been eliminated by nature. The restoration of fluid balance is most important, particularly in the very young and old. Streptomycin, chloromycetin, terramycin, and aureomycin reduce the number of organisms in the intestinal tract.

k. Epidemicity. The infection is contagious. Epidemics usually occur when mass consumption of contaminated food occurs. Explosive epidemics occur in animals, particularly rodents, and many surviving animals become chronic carriers. Spread of the infection can be halted by elimination of carriers as food handlers, proper sanitation, pasteurization of milk, elimination of rodents and flies where food is prepared, and careful handling and adequate cooking of food.

l. Stability. Stability of this organism is typical of the group; see paragraphs 57*l* and 58*l*.

60. Mycobacterium Tuberculosis

a. Description. Tubercle bacilli are slender straight or slightly curved rods with rounded ends. They vary from 0.2 to 0.5 micron in width and from 1 to 4 microns in length. They are acidfast, nonmotile, and gram-positive and are strictly aerobic.

b. Disease Produced. Pulmonary tuberculosis is characterized by severe lung involvement accompanied by cough, fever, fatigue, and loss of weight. This form of the disease is the chief cause of morbidity and mortality. The primary type is acute, healing or progressing in a relatively short time, and is most commonly seen in infants and children and occasionally in adults who have escaped childhood infection. Adults acquiring their first infection may manifest the postprimary type, passing through the primary phase inconspicuously because of its rapid development. The postprimary (reinfection) type is more stable and

more chronic than the primary type and is associated with a significant, but inadequate, degree of resistance. Tuberculosis infection in the bones, joints, skin, or other tissues is usually caused by the bovine variety of *M. tuberculosis,* although this type may also invade the lungs.

c. Source of Infection. Infection is acquired from persons with draining lung cavities. Tuberculous cattle, particularly their raw milk, is the source of the bovine variety, which is rare in the United States.

d. Mode of Transmission. Transmission usually occurs through the discharges of the respiratory tract, by direct or indirect personal contact. In the United States, primary infection is almost always a result of inhalation of the bacilli in droplet form. The postprimary type of tuberculosis may be caused either by organisms which have survived in primary lesions or by newly inhaled bacilli. The bovine type is acquired by contact with tuberculous cattle or ingestion of their raw milk but can be transmitted also by the same route as the human type, from person to person. Natural infection usually requires continued and intimate exposure.

e. Incubation Period. This period is variable, depending on dosage, age, and other factors, but probably is not less than 1 month. The period may be reduced considerably by exposure to heavy concentrations of the organism.

f. Susceptibility and Resistance. Man is very susceptible to tuberculous infection but remarkably resistant to tuberculous disease. Susceptibility to the disease is dependent upon age, race, family characteristics, and previous exposure to the organism. It is lowest in persons from 3 to 12 years of age and is greater in the undernourished and fatigued and among peoples who have not previously been exposed to the disease. In the United States the rapidly progressive primary type is seen more often in young adult Negroes than in white adults. Recovery from the disease leaves no solid immunity, but resistance is altered so that reinfection is not as acute as the previous infection. The chance of contracting progressive clinical tuberculosis is higher in tuberculin-negative than in tuberculin-positive individuals.

g. Prevalence. Tuberculosis is one of the most common of the infectious diseases of man. It occurs in all parts of the world, although it has never appeared in some isolated groups of people. Infection is widespread in the urban population, as is shown by the 50 to 95 percent tuberculin reactor rate, but the progressive disease develops in only a small proportion of those infected.

h. Mortality. Fatality rate is high, especially among infants, adult males up to old age, and adolescent and young adult females. Despite the many improvements in case-finding and the newer therapeutic procedures, tuberculosis is still among the ten leading causes of death in the United States.

i. Immunization. Vaccination of tuberculin-negative persons with living strains of attenuated tubercle bacilli of Calmette and Guerin (BCG) confers some protection against naturally acquired tuberculous disease (primary and postprimary). However, prevention and control of tuberculosis depends largely upon detection and isolation of carriers and the general improvement of environmental and economic conditions.

j. Treatment. Streptomycin, particularly when combined with para-aminosalicylic acid (PAS) or isonicotinic acid hydrazide (INH), is valuable in arresting the disease, particularly in its acute manifestations, but this treatment in itself is not curative. Success in treatment depends upon supportive therapy, including rest, good food (supplementing the diet with vitamins A, C, and D), and fresh air. Local rest of the lungs is promoted by several methods. Surgery is required in some cases.

k. Epidemicity. The spread of tuberculosis occurs in large part through continued family or household case association, the disease being transmitted slowly from one generation to the next. Under favorable conditions, epidemic outbreaks may take place. Occurrence is influenced by occupation, as by continued exposure to mineral (silica) dust, which predisposes to infection.

l. Stability. When organisms are exposed to direct sunlight, in artificial culture they are killed in 2 hours but in sputum under the same conditions they may survive 20 to 30 hours. When organisms are protected from the sun, they will live in putrefying sputum for weaks and in dried sputum for as long as 6 to 8 months. They are resistant to the usual chemical disinfectants, 24 hours being required for the decontamination of sputum by 5 percent phenol, but possess no greater resistance to moist heat than other bacteria do, being killed in 15 to 20 minutes at 140° F. Pasteurization is effective in destroying the organisms in milk.

Section III. RICKETTSIAE

61. Rickettsia Prowazeki

a. Description. The micro-organism is a nonmotile, minute, coccoid or rod-shaped rickettsia, occurring sometimes in pairs or chains, with a diameter of about 0.3 micron and with varied sizes and shapes.

b. Disease Produced. The disease is known as classic epidemic (human or louse-borne) typhus. It is an acute infectious disease of man and is characterized by severe headache, sustained high fever, general pains, and a skin rash.

c. Source of Infection. Infections are acquired from persons with the disease.

d. Mode of Transmission. Transmission is mainly by body lice which have fed upon infected persons. The individual becomes infected usually by scratching or rubbing louse feces into a wound made by the louse bite; by crushing an infected louse on the skin; or by rubbing louse feces into the eyes. It is possible that louse feces from dirty clothing may be transmitted through the air to the respiratory tract.

e. Incubation Period. Incubation is from 6 to 15 days, averaging 12 days.

f. Susceptibility and Resistance. All peoples are susceptible. One attack confers immunity, which is not always permanent.

g. Prevalence. The disease is widely distributed in peoples living under crowded and unhygienic conditions (famine, war), particularly in Europe and Asia. Cases occur throughout the year, with increase in the cold months.

h. Mortality. Mortality is from 10 to 80 percent, varying in different epidemics and with the age of individuals.

i. Immunization. Some vaccines confer considerable protection of uncertain duration; immunization should be repeated every 4 months where danger of typhus is present. The vaccine reduces risk of infection, modifies the course of the disease, and lowers the mortality.

j. Treatment. The course of the disease can be shortened by use of appropriate chemotherapy and antibiotics (chloromycetin, aureomycin, terramycin). Supportive treatment and prevention of secondary infections are essential.

k. Epidemicity. The disease is not contagious or communicable from man to man. Epidemics usually occur in winter under crowded and unsanitary conditions, particularly during famine and war, and when the population is heavily infested with body lice. Louse eradication is used to control epidemics.

l. Stability. The organism is destroyed by heat at 112° F. in 15 to 30 minutes and inactivated by use of 0.1 percent formalin and 0.5 percent phenol.

62. Rickettsia Mooseri (Rickettsia Typhi)

a. Description. This rickettsia is similar to *Rickettsia prowazeki,* but with less variation in appearance.

b. Disease Produced. Murine (endemic, rat, or flea-borne) typhus is similar to classic epidemic typhus except that the disease is milder and has a slower onset.

c. Source of Infection. Infected rodents, particularly rats, are sources of infection.

d. Mode of Transmission. The disease is transmitted from rodents to man by the bite of the rat flea.

e. Incubation Period. The incubation period ranges from 6 to 14 days, mostly 12 days.

f. Susceptibility and Resistance. Susceptibility is general. One attack confers immunity, which sometimes is not permanent.

g. Prevalence. The disease is widely distributed in temperate, subtropical, and tropical countries. It is transmissible to man throughout the year, with increase in summer and fall.

h. Mortality. Case fatality rate is about 2 percent, increasing in older people (over 50 years of age).

i. Immunization. Vaccine similar to that for classic epidemic typhus is probably equally effective.

j. Treatment. Treatment is similar to that for classic epidemic typhus. Delayed recognition of the disease may result in the optimum period of treatment being passed.

k. Epidemicity. The disease is not contagious. Rodent and flea eradication are the most successful control measures.

l. Stability. Stability is the same as for classic epidemic typhus.

63. Rickettsia Tsutsugamushi

a. Description. This rickettsia appears as small diplococcuslike structures or short rods which are 0.3 to 0.5 micron in length and 0.2 to 0.4 micron in width.

b. Disease Produced. Scrub typhus (tsutsugamushi disease or mite-borne typhus), an acute infection in man, is characterized by sudden onset with chills and fever and headache which may increase in intensity. A dull red eruption appears on the trunk of the body on the fifth to eighth day, and may extend to the arms and legs. Cough and other signs of pneumonia are frequently present.

c. Source of Infection. The rickettsia is perpetuated in infected mites, where it is passed from generation to generation and is maintained by the mites feeding on susceptible wild rodents, particularly mice and rats of different species.

d. Mode of Transmission. Transmission to man is made by the bite of infected larval mites.

e. Incubation Period. The incubation period is from 7 to 10 days, sometimes as long as 14 days.

f. Susceptibility and Resistance. Susceptibility is general. One attack confers immunity, which is not always permanent.

g. Prevalence. The disease occurs in southeastern Asia, including India, Burma, Malay States, French Indochina, islands of the West and South Pacific, Japan, Formosa, Sumatra, Java, New Guinea, North Queensland, and Australia. Transmission is limited to summer months in Japan but may occur throughout the year near the equator.

h. Mortality. Mortality varies with age and locality and may go as high as 50 percent.

i. Immunization. There is no effective vaccine available for general use. The immunity produced in man (by scrub typhus) is not as permanent as that produced by other rickettsiae.

j. Treatment. Prompt use of an appropriate antibiotic (chloromycetin) is highly effective.

k. Epidemicity. The disease is not communicable from man to man. Control is by elimination of rodents and eradication of mites.

l. Stability. Stability is the same as for typhus rickettsiae.

64. Rickettsia Rickettsii

a. Description. The rickettsia is a diplococcuslike micro-organism, with the distal ends tapered so that the pairs resemble minute pneumococci. The average is 1 micron in length and 0.2 to 0.3 micron in width.

b. Disease Produced. Rocky Mountain spotted fever (Sao Paulo fever in South America), an acute infectious disease, is characterized by fever and joint and muscular pains. A skin rash usually appears on the third or fourth day, rapidly spreading from the ankles and wrists to the legs, arms, and chest.

c. Source of Infection. Infected ticks such as the common dog tick in the eastern and southern United States, the wood tick in the northwestern United States, and, occasionally, the lone star tick in the southwest are sources of infection. In other countries the vectors may be other species of ticks. The infection is passed from generation to generation in ticks and is probably maintained by larvae feeding on susceptible wild rodents.

d. Mode of Transmission. The disease is transmitted to man by the bite of an infected tick, by contamination of abraded skin with infected tick tissues or feces, or by contact of tick tissues with unbroken skin.

e. Incubation Period. The incubation period is from 3 to 10 days.

f. Susceptibility and Resistance. Susceptibility is probably general; recovery from an attack is followed by immunity, which may or may not be permanent.

g. Prevalence. The disease occurs throughout North America and in some parts of South America. Predominant occurrence is in spring and early summer, when adult ticks appear.

h. Mortality. Fatality rate may vary from 20 to 60 percent, depending on locality.

i. Immunization. An effective egg-yoke vaccine is available, which lessens the chance of infection and lowers the mortality rate. Yearly booster doses are needed to attain maximum protection.

j. Treatment. Appropriate antibiotics (chloromycetin, aureomycin, and terramycin) are effective in reducing fatality and shortening the course of the disease. Supportive treatment also is indicated.

k. Epidemicity. The disease is not communicable from man to man. Tick eradication and preventive immunization are the best control measures.

l. Stability. The rickettsia can be killed by exposure to a temperature of 112° F. for 10 minutes and by drying in 10 hours. It is inactivated by 0.1 percent formalin and 0.5 percent phenol.

65. Coxiella Burneti (Rickettsia Burneti)

a. Description. This rickettsia is a bacteriumlike, gram-negative organism which may vary in size and shape from a lanceolate rod 0.25 by 0.5 micron to a diplobacillus 0.25 by 1.5 microns. Because the small forms will pass through bacterial filters, they are considered by some to be viruses.

b. Disease Produced. Q fever, also known as nine mile fever and (North) Queensland fever, is an influenzalike disease that is moderately incapacitating and is characterized by an acute fever of sudden onset, headache, chills, weakness, and sever perspiration. Pulmonary involvement occurs in the majority of cases, accompanied by mild cough, scanty expectoration, and chest pains. Q fever is distinguished from other rickettsial diseases in its failure to cause a skin rash.

c. Source of Infection. Cows, sheep, goats, ticks, and wild animals appear to be natural reservoirs, with numerous ticks transmitting the disease among them. The organism may be found in the milk and mammary glands of infected cows, in the milk of sheep and goats, and in dust-laden air of dairy cattle barns and goat pens which harbor infected animals.

d. Mode of Transmission. In man the disease appears to be transmitted by inhalation of infected dust from one source or another as well as by ingestion. Raw milk from cows and goats, dried milk, raw wool, hides, infected meat, goat hair, and tick feces, as well as cultures of infected tissues, have been involved in infections.

e. Incubation Period. The incubation period is from 14 to 26 days with a mean of 19 days.

f. Susceptibility and Resistance. Susceptibility is general. An attack confers immunity of long duration.

g. Prevalence. The disease has been reported in many parts of the United States, particularly in California; it has also been reported in Australia, the Mediterranean area, Western Europe, the Near East, the Balkans, Spain, England, Panama, and scattered areas of Africa.

h. Mortality. Fatalities are rare, but may be up to 4 percent in epidemics.

i. Immunization. Vaccines, although in the experimental state, have been very effective when used by laboratory personnel and slaughterhouse and stockyard workers.

j. Treatment. Appropriate antibiotics (aureomycin, chloromycetin, and terramycin) may be effective, although they have not been completely evaluated. Supportive treatment is indicated.

k. Epidemicity. The disease is relatively noncontagious. Outbreaks have occurred among slaughterhouse and stockyard workers in the United States.

l. Stability. The micro-organism is resistant to temperature changes from 72° F. to −94° F., is resistant to 0.5 percent phenol, and is relatively resistant to desiccation. It is killed by 0.5 percent formalin. It probably persists on surfaces for 5 to 60 days.

Section IV. VIRUSES

66. Psittacosis Virus

a. Description. This organism, usually classed as a virus, has been classed by some as a rickettsia but more recently has been placed tentatively in a group intermediate between viruses and rickettsiae. It is small and coccoid, is 0.2 to 0.4 micron in length, and is gram-negative. Although the name *Miyagawanella psittacii* has been applied to this virus, it has not been generally accepted.

b. Disease Produced. Psittacosis or parrot fever is also called ornithosis. The disease is often confused with influenza, atypical pneumonia, and typhoid fever. It is a severe febrile disease in man; the onset may be sudden or may be gradual and insidious. It is characterized by acute pulmonary infection, chills, fever, anorexia, sore throat, severe headache, backache, constipation, great weakness, and prostration and is sometimes accompanied by delirium.

c. Source of Infection. Parrots, parakeets, love birds, canaries, pigeons, and other birds are sources of infection.

d. Mode of Transmission. The respiratory tract is the principal portal of entry. Transmission is made by contact with infected birds or by breathing of air contaminated by feces, urine, nasal discharges or soiled feathers of sick, dying, or latently infected birds. Contaminated air may travel a considerable distance before it loses its infectivity. Apparently well birds (carriers) transmit the infection. Transmission from man to man has occurred, and in rare instances man has become a carrier.

e. Incubation. Incubation is usually from 6 to 15 days with 10 days as the mean, but it may be as long as 30 days.

f. Susceptibility and Resistance. All ages and races are susceptible. Children are readily infected but rarely develop sever illnesses. The disease is more severe in adults than in children. Recovery from an attack is generally followed by immunity, although reinfections have been reported.

g. Prevalence. The disease is widely distributed throughout the world. It is most prevalent in areas where parrots, parakeets, and similar birds are found. It usually occurs as a sudden outbreak among persons exposed to infected birds. Mild cases may occur from slight exposure to infected pigeons or to birds showing no symptoms of the disease.

h. Mortality. Mortality is variable, from 9 to 20 percent in untreated cases, and usually occurs among persons over 30 years of age.

i. Immunization. Immunization measures are in an experimental stage.

j. Treatment. Sulfadiazine, penicillin, aureomycin, chloromycetin, and terramycin shorten the course of the disease and greatly decrease the mortality.

k. Epidemicity. The disease tends to be self-limiting. Transfer from man to man may occur by close contact, such as patient to attendant.

l. Stability. The virus will remain viable on surfaces for 20 to 30 days and perhaps longer in dry fecal material. It is inactivated in 24 to 36 hours by 0.1 percent formalin and 0.5 percent phenol. Decontamination may be accomplished by burning of infected material or by disinfection of infected feces. Two percent cresol is an effective disinfectant.

67. Encephalitis and Encephalomyelitis Viruses

a. Description. These viruses are small neurotropic organisms. They are distinguishable antigenically, but some are so closely related that they appear to be variants of a common ancestor.

b. Diseases Produced. There are several types of encephalitic diseases, each produced by a specific virus. Their clinical pictures are

similar, varying mainly in severity and rate of progress of symptoms. They are characterized by inflammation of the menings of the brain, headache, fever, dizziness, drowsiness or stupor, tremors or convulsions, severe prostration, occasional paralysis, and muscular incoordination. The diseases are usually acute, prostrating, and of short duration. The following are some of the more common types:

(1) St. Louis encephalitis is endemic and epidemic in central and western United States and prevails in summer and fall when the arthropod vectors are most numerous.

(2) Eastern equine encephalomyelitis and Western equine encephalomyelitis occur usually in summer in Canada, the United States, and Central and South America. They are viral diseases of lower animals, especially of horses and mules, and are transmissible to man.

(3) Venezuelan equine encephalomyelitis occurs in Central and South America. It is a disease primarily of equine animals; when the disease is transmitted to man, it usually induces a mild case with varied symptoms.

(4) Japanese B-type encephalitis occurs in Japan, Korea, China, and some Pacific islands.

(5) Russian Far East encephalitis occurs in spring and early summer, mainly in the Far East provinces of Russia and less frequently in European and Siberian Russia.

c. Sources of Infection. Wild and domestic birds are the principal sources of mosquito infection for the virus types occurring in the United States. The equines, or horses, are also hosts but are not as important sources of mosquito infection as are birds.

d. Mode of Transmission. Mosquitoes transmit all types except the Russian spring-summer type, which is tick-borne.

e. Incubation Period. The incubation period is variable, ranging from 2 to 15 days.

f. Susceptibility and Resistance. Susceptibility ranges from 90 to 100 percent and is usually high in the very young and the aged. Recovery from an infection results in an excellent short-term immunity to the specific virus, but not to any other type.

g. Prevalence. The diseases are usually prevalent in summer and early fall; they are usually limited to areas and years of sustained high temperature and large numbers of mosquitoes. Highest rates are in rural and suburban localities.

h. Mortality. Mortality is unknown; it is probably 5 to 60 percent with all types. Japanese B and Eastern equine types have the highest case fatality.

i. Immunization. Some effective virus vaccines have been developed on a small scale, but widespread use is not practicable at present.

j. Treatment. Treatment is supportive only; chemotherapy and antibiotic treatments have not been developed.

k. Epidemicity. The disease is irregularly epidemic in dry farming areas of the midwestern, southwestern, and eastern United States and endemic in many hot, irrigated, western United States valley areas. Transmission from man to man is not known to occur but may be possible by means of respiratory droplet infection. Transmission of the Venezuelan equine encephalomyelitis by inhalation has occurred accidentally in laboratories.

l. Stability. Stability varies among the different types. All may be preserved frozen at —94° F. St. Louis and Japanese B viruses are inactivated at 133° F. in 30 minutes; Russian Far East virus is inactivated at 140° F. in 10 minutes, but the Western and Eastern equine viruses withstand this treatment and also resist 0.2 percent chloroform, 1 or 2 percent phenol, and 0.05 percent mercuric chloride. St. Louis and Russian viruses are inactivated by 1 percent formalin within a day; the Russian is inactivated by 1 percent phenol in 10 days, but the St. Louis resists this treatment for at least 25 days.

68. Influenza Virus

a. Description. The virus is large, having strains which range between 0.07 and 0.1 micron in size. Types A and B have been identified, and there are indications that type C may come to be recognized.

b. Disease Produced. Influenza or *la grippe* is an epidemic disease, occasionally pandemic, which is characterized by catarrhal inflammation of the respiratory tract; sudden onset; fever of 1 to 7 days' duration; marked prostration; and generalized aches and pains in back, limbs, and muscles. Sore throat, bronchitis, and pneumonia are complications of secondary bacterial infections.

c. Source of Infection. Soiled articles and discharges from the mouth and nose of infected persons are sources of infection.

d. Mode of Transmission. Transmission is probably by direct contact, by droplet infection (respiratory), or by articles freshly contaminated with nose and throat discharges of infected individuals.

e. Incubation Period. The incubation period for type A is from 1 to 2 days; for type B it is from 12 to 18 hours.

f. Susceptibility and Resistance. The virus is highly infective and contagious; susceptibility is general, there being relatively little natural resistance. Resistance of some individuals exposed to the disease during epidemics appears to be due to previous infection. Acquired immunity following recovery from an attack lasts only for a few month

to a year, and is effective only against specific strains of the virus. Artificial immunization methods produce a specific immunity of short duration.

g. Prevalence. Prevalence is variable; the disease occurs sporadically as epidemics and pandemics. Epidemics may affect up to 50 percent of a given population within 4 to 6 weeks.

h. Mortality. The disease has a mortality range from 0 to 1 percent, but it is often followed by complicating respiratory infections which result in high mortality.

i. Immunization. Vaccination with specific strains of the virus leads to an effective immunity of several months' duration against the same or closely related strains. The extreme antigenic variability of the influenza viruses makes it difficult to protect against all strains.

j. Treatment. Treatment is supportive only, with control of secondary infections. There is no specific effective treatment.

k. Epidemicity. Epidemics are widely prevalent under favorable conditions. Pandemics occur irregularly.

l. Stability. The virus is killed by being heated at 132° F. for 20 to 30 minutes; it is resistant to freezing for several weeks. It can also be easily destroyed by steam, boiling, and ordinary antiseptics.

69. Variola Virus

a. Description. The virus will pass through most filters and ranges from 0.15 to 0.2 micron in size.

b. Disease Produced. Smallpox, or variola, a highly contagious and often fatal disease, is characterized by severe fever and small blisters of the skin. The blisters later contain pus and form crusts which fall off in 10 to 40 days after the first lesions have appeared, leaving pink scars which gradually fade. Complications of the disease are secondary bacterial infections.

c. Source of Infection. Lesions of the mucous membranes and skin of infected persons are sources of infection.

d. Mode of Transmission. Transmission is made through contact with patients having the disease or with articles or persons freshly contaminated by discharges from lesions and skin of infected individuals.

e. Incubation Period. Incubation is from 7 to 21 days, commonly 12 days.

f. Susceptibility and Resistance. The disease is highly contagious and infectious, with universal susceptibility. Recovery usually is followed by permanent acquired immunity.

g. Prevalence. Prevalence is world-wide, except in immunized or

nonexposed populations. The frequency is greatest in winter and least in summer.

h. Mortality. Fatalities range from 1 percent with the mild type of disease to 30 percent with the more severe types.

i. Immunization. Artificial immunity by vaccination may be completely effective for 2 to 20 years, but revaccination every 3 years is advisable to maintain minimal immunity. A high degree of immunity is required against severe strains of the virus.

j. Treatment. No specific treatment is available. Antibiotics and sulfa drugs are used to treat secondary infections.

k. Epidemicity. Epidemicity is high, depending on immunity status of population and exposure to the disease.

l. Stability. The virus is viable in water for several years at 39° to 48° F. and is resistant in dry or wet form to very low temperatures. In the dry state it is more resistant than in the wet state. Decontamination can be effected by exposure to alcohol and acetone for 1 hour at room temperature, but the virus is resistant to some other disinfectants. Moist heat above 140° F. and dry heat above 212° F. are effective in 10 minutes.

70. Yellow Fever Virus

a. Description. The virus particles are estimated to range from 0.017 to 0.028 micron in size and pass through most filters.

b. Disease Produced. Yellow fever (classic urban) is characterized by sudden onset, chills and fever, prostration, headache, backache, muscular pain, congestion of mucous membranes, severe gastrointestinal symptoms, and jaundice (yellowing of skin) from liver damage. Hemorrhage from the stomach and gums often occurs. The disease if of short duration, with either death or complete recovery occuring within 2 weeks of onset. A forest or sylvatic form in South America and Africa is known as jungle yellow fever and appears to be clinically identical to the classic type.

c. Source of Infection. The blood from people and monkeys infected with yellow fever is the source of infection.

d. Mode of Transmission. Transmission is ordinarily by the bite of the female *Aedes aegypti* mosquito; in the forests of South America and Africa, it is usually by some other types of mosquito.

e. Incubation Period. Incubation is from 3 to 6 days, rarely longer.

f. Susceptibility and Resistance. Susceptibility is general. Recovery from an attack is followed by lasting immunity. Infants born to immune mothers are immune for 3 to 4 months. Negroes are more resistant than whites.

g. Prevalence. The disease is endemic in man, monkeys, and some other mammals in Western and Central Africa and among certain apes and monkeys in the tropical forests of Central and South America. Occasional human cases and epidemics occur in these areas and neighboring urban or rural localities. The disease is unknown in the Pacific basin.

h. Mortality. The overall case fatality rate, taking into account undiagnosed mild infections (shown by the later presence in the blood of specific antibodies), is probably about 5 percent. However, it is much higher in cases in which jaundice appears.

i. Immunization. Inoculation with a modified living virus vaccine confers an active immunity that may last for at least 4 years and probably longer.

j. Treatment. There is no specific treatment. Supportive treatment (bed rest and fluids) is essential for even the mildest cases.

k. Epidemicity. Occasional epidemics still occur in Africa and South and Central America. These epidemics can be lessened by mosquito control and active immunization.

l. Stability. The virus is resistant to freezing and drying but is destroyed by being heated at 140° F. or above for 10 minutes. It is rather easily inactivated by common antiseptics. Mosquito control measures, including use of insecticides, are the preferred methods of control.

71. Dengue Fever Virus

a. Description. This is a very small virus, about 17 to 25 millimicrons in size.

b. Disease Produced. Dengue fever, an acute, extremely disabling disease usually of sudden onset, is characterized by fever, chilliness, intense headache, backache, pain behind the eyes, joint and muscle pains, weakness and prostration, and irregular rash. The fever, rarely exceeding 105° F., lasts for 5 or 6 days and usually terminates abruptly after reaching a peak. Loss of appetite and constipation are common during the entire illness, and abdominal discomfort with colicky pains and tenderness may be manifested. The acute phase lasts only about a week, but convalescence may take several weeks. Dengue is said to be temporarily the most incapacitating although the least fatal of epidemic diseases.

c. Source of Infection. Sources of infection are the blood of infected persons one day before and up to 5 days following onset; infected mosquitoes; and, in some regions, possibly the blood of infected monkeys.

d. Mode of Transmission. The disease is transmitted by the bite of the *Aedes aegypti* mosquito and certain other species of *Aedes* which have become infected by biting a patient.

e. Incubation Period. Incubation is from 3 to 15 days, most often 5 to 8 days.

f. Susceptibility and Resistance. All persons except natives of endemic areas appear to be fully susceptible. Immunity to the invading strain is apparently permanent, but reinfection with a different strain is possible. However, if this occurs within a few months of the primary infection, the disease is much milder because of cross-immunity.

g. Prevalence. The disease is found mainly in the tropics and subtropics, extending to the Gulf Coast of the United States, but it may occur whenever the vector mosquitoes exist.

h. Mortality. Fatality rate is very low.

i. Immunization. A mouse-adapted virus vaccine has been found to be stable, safe, and effective in studies on human volunteers and will probably be useful in control of epidemics and for troops going from nondengue to dengue fever areas.

j. Treatment. There is no specific therapy, but supportive treatment is essential.

k. Epidemicity. The virus does not spread directly from person to person. Epidemics occur in areas where vector mosquitoes are present in large numbers. The infectivity rate is extraordinarily high, 75 to 100 percent of the inhabitants of a locality being attacked. Spread of the disease can be prevented by diligent mosquito control.

l. Stability. Blood from a patient remains infectious after storage in a refrigerator for several weeks. The virus may be preserved in a frozen and dried state at 41° F. for at least 5 years. Mosquitoes do not transmit the infection through their eggs to the young, but the infected insects probably remain so for life. The virus is inactivated by ultraviolet light and by 0.5 percent formalin.

72. Hepatitis Viruses

a. Description. There are two strains of hepatitis virus, virus A of infectious hepatitis and virus B of serum hepatitis (homologous serum jaundice).

b. Diseases Produced. Infectious and serum hepatitis are characterized first by fever, loss of appetite, nausea, fatigue, headache, and abdominal discomfort. After a few days the fever subsides; then, because of liver damage, bile may be present in the urine, and jaundice (yellowing of the skin) appears.

c. Source of Infection. Sources of infection of virus A are discharges from the nose, mouth, and gastrointestinal tract of infected persons; sources of infection of virus B are blood, serum, or plasma from infected persons.

d. Mode of Transmision. The usual mode of transmission for virus A is unknown but may be by contaminated water, food, or milk, or by direct personal contact. Virus B is transmitted by transfusions of infected blood, serum, or plasma, or in immunizing serums prepared from infected human serum.

e. Incubation Period. Incubation is long and variable—15 to 40 days for virus A, 40 to 150 days for virus B.

f. Susceptibility and Resistance. Susceptibility is general. Immunity following an attack is undetermined, but second attacks are infrequent. No other animal than man is known to be susceptible.

g. Prevalence. The disease is common and is apparently world-wide in distribution. It is most prevalent in the fall and winter months.

h. Mortality. Mortality is less than 0.5 percent.

i. Immunization. There is no vaccine available at the present time. Gamma globulin provides protection against virus A for several weeks.

j. Treatment. Treatment is supportive and includes diet therapy, vitamins K and B.

k. Epidemicity. Epidemics are most common in institutions and rural areas. General incidence is about the same in rural and urban areas and is most common in children and young adults. Epidemics occur in early winter, sometimes reaching a peak in late winter and extending into spring. Epidemics are controlled by the practice of good sanitation and personal hygiene, particularly in sanitary disposal of respiratory discharges and feces; by the elimination of flies; and by the use of disease-free blood or blood products in transfusions and in the preparation of vaccine.

l. Stability. The virus withstands a temperature of 133° F. for at least 30 minutes. It is destroyed by boiling or autoclaving for 15 minutes. Virus A is unaffected by the normal concentration of chlorine added to drinking water. Virus B survives in the frozen state for several years and resists desiccation at room temperature or exposure to 0.25 percent phenol for at least a year. Virus B has been inactivated in serum by exposure to ultraviolet light for 45 minutes.

Section V. FUNGI

73. Coccidioides Immitis

a. Description. In man and animals, the fungus occurs as thick-walled endospore-filled spherules, 20 to 80 microns in diameter; in artificial culture, it appears as a fluffy white cottony mold.

b. Disease Produced. Coccidioidomycosis is a highly infectious disease. The usual primary form (known as valley or San Joaquin fever)

is an acute, disabling, self-limiting respiratory infection resembling influenza with usually a low grade fever of 99° F. to 101° F. and a slight nonproductive cough. The secondary, progressive form (known as coccidioidal granuloma) is a chronic, malignant, disseminated infection which involves any and all organs of the body, including skin and bones, and produces numerous abscesses. The progressive form has a high fatality rate. A primary localized form of infection may occur on the exposed surfaces of the skin; it sometimes develops into the progressive, disseminated form of infection.

c. Source of Infection. Dust, soil, and vegetation contaminated with spores of this fungus are sources of infection.

d. Mode of Transmission. Transmission is made by inhalation of spores in dust from soils and dry vegetation and possibly through skin scratches or wounds.

e. Incubation Period. The incubation period for the primary pulmonary form is 10 to 21 days, the average being about 12 days. The clinically active cases in about 1 percent of whites and a much higher percentage of Negroes develop into the progressive form of the disease, usually within a period of weeks or months after onset of the primary infection. The progressive form is not necessarily preceded by symptoms of primary infection.

f. Susceptibility and Resistance. Susceptibility to the primary infection is general. With the progressive form of the disease, Negroes and Orientals appear to be much more susceptible than whites, and females are less apt to develop granulomatous lesions than are males. Probably up to 60 percent of infected persons have no symptoms but become immune.

g. Prevalence. Recognized endemic areas are the arid southwestern United States, northern Mexico, Central America, and the Chaco region of South America, involving Bolivia, Paraguay, and Argentina. Incidence is highest in hot, dry weather.

h. Mortality. Fatalities are about 50 percent in the secondary, progressive form.

i. Immunization. Vaccine therapy is only in the experimental stage of development, and present prospects for a good vaccine are poor.

j. Treatment. Supportive treatment, with complete rest, is the standard procedure. Progressive coccidioidomycosis is very resistant to specific chemotherapy, but some cases have shown improvement under treatment with prodigiosin, stilbamidine, or ethyl vanillate. Localized lesions may be treated by X-ray or surgery. Prognosis is excellent in the primary pulmonary infection, good in the primary cutaneous type, and very poor in the disseminated, progressive disease, especially in the Negro.

k. Epidemicity. The disease is noncontagious. Small epidemics may occur in hot, dry seasons when large numbers of individuals, such as troops, are stationed in endemic areas or engaged in maneuvers in these areas. Dust control, such as paving roads and runways, oiling athletic fields, and planting lawns in endemic areas is effective in reducing the number of infections.

l. Stability. Spores of the fungus are highly resistant to drying and will live for months or years in culture or in the soil (dust). They are destroyed by autoclaving for 15 minutes or by exposure to formaldehyde fumes for 48 hours. Decontamination of large areas, even if possible, would not appear to be practicable.

74. Histoplasma Capsulatum

a. Description. The fungus appears as small (1 to 5 microns), oval, yeastlike intracellular bodies in the tissues of man and animals and in culture on sealed, blood agar slants at 96 to 98° F. In culture at room temperature, it forms a white, cottony, filamentous moldlike growth.

b. Disease Produced. Histoplasmosis is a chronic, local or systemic, infectious disease of man and in animals. It is characterized by low grade granulomatous lesions of the skin or mucous membranes and/or tuberculosis-like lesions of the lungs and by involvement of internal organs, especially the spleen and liver. Less than 1 percent of naturally occurring primary infections develop into the progressive and usually fatal form of the disease.

c. Source of Infection. Dust contaminated with spores of this fungus is a source of infection. The agent has been recovered from man, dogs, cats, rodents, skunks, and opossums and from the soil and air.

d. Mode of Transmission. Transmission is usually by inhalation of spores in dust from soils and dried organic matter; it may also be by ingestion or through skin scratches.

e. Incubation Period. In the few reported epidemics, symptoms appeared within 5 to 18 days following exposure.

f. Susceptibility and Resistance. Susceptibility is general. The occurrence and severity of clinical symptoms depend upon dosage of infectious agent. The extreme infectiousness of the disease is shown by a positive histoplasmin skin test in 80 percent or more of the adult population in local endemic areas. The effect of dosage is illustrated by essentially 100 percent epidemic involvement among groups exposed to highly contaminated dust in inclosed places.

g. Prevalence. Histoplasmosis is endemic in the central Mississippi and Ohio River valleys and in other scattered areas including the St. Lawrence River valley, eastern North Carolina, and parts of Mexico and Panama. However, cases have been reported also from many other

parts of the world, including South America, Europe, Africa, Australia, and the Pacific Islands.

h. Mortality. The acute pulmonary form of the disease has a very low fatality rate unless it disseminates. The progressive form is usually fatal.

i. Immunization. Immunization has not been developed.

j. Treatment. Supportive treatment is used. Ethyl vanillate has been effective in many cases. Among other promising drugs being developed is hydroxystilbamidine. Surgery is curative in localized lesions.

k. Epidemicity. The disease is noncontagious.

l. Stability. Spores are viable for several months and probably years in dry soil and for a period of months in tap water at temperatures ranging from near freezing to 98° F. They are destroyed by heat at 131° F. for 15 minutes and by 1 to 2 percent formalin in 24 hours.

75. Nocardia Asteroides

a. Description. This aerobic fungus has characteristics of both molds and bacteria and has been classified in an intermediate position. It usually forms orange colonies consisting of gram-positive, weakly acid-fast, branching filaments, 1 micron or less in diameter. In both culture and tissues it tends to fragment readily into bacillary and coccoid forms. The acidfast rodlike fragments may be mistaken for tubercle bacilli.

b. Disease Produced. Nocardiosis, a severe pulmonary infection, is similar in many respects to tuberculosis but tends to form numerous abscesses instead of tubercles and is characterized by chronic pneumonia. It tends to spread to other organs of the body, especially the brain, where abscesses are formed. The disease often takes other forms, such as localized subcutaneous abscesses and tumors. Pulmonary infection is characterized by general malaise, fever, productive cough, night sweats, loss of appetite, and loss of weight. Brain involvement (tumor or abscess) presents symptoms of headache, nausea, and vomiting.

c. Source of Infection. Soil, dust, or vegetation contaminated with the organism are sources of infection.

d. Mode of Transmission. The disease is transmitted by contaminated dust and possibly by droplet infection or through pus and other discharges from infected individuals. Skin infections usually result from contamination of wounds or scratches.

e. Incubation period. The incubation period in man is unknown; experimental infection in guinea pigs is usually fatal within a week.

f. Susceptibility and Resistance. Susceptibility to pulmonary infec-

tion is probably general and is dependent to a great extent upon dosage. Special predisposing factors may be required for production of progressive infection, since the organism is apparently widely distributed, but relatively few cases are reported. It is not known whether recovery provides any immunity.

g. Prevalence. The disease is world-wide.

h. Mortality. The death rate is very high in untreated or advanced cases of generalized infection, perhaps close to 100 percent. Early diagnosis and vigorous treatment with sulfonamides result in the cure of most cases.

i. Immunization. Active immunization in man has not been tried; in animals, experimental immunization has produced an active protective immunity.

j. Treatment. The sulfonamides, particularly sulfadiazine alone or combined with sulfamerazine, offer effective treatment. Supportive treatment is essential.

k. Epidemicity. The disease is not known to spread from man to man or from animal to man, but infection by droplet spray or through infection of wounds by contaminated dressings and other material is possible.

l. Stability. As the fungus exists normally in soil, it is presumed to be quite resistant to adverse environmental conditions.

Section VI. TOXINS

76. Botulinum Toxin

a. Description: This is the proteinlike exotoxin formed by the botulinum bacillus. Through repeated purification procedures, it has been obtained in a crystalline form and is the most powerful poison known. the crude material or "mud" is a brownish, amorphous mass. There are at least five distinct types, A, B, C, D, and E, of which types A, B, and E are known to be toxic for man; C and D are toxic for animals and probably for man.

b. Disease Produced. Botulism is a highly fatal, acute poisoning, It is characterized by vomiting, constipation, thirst, general weakness, headache, fever, dizziness, double vision, dilation of the pupils, paralysis of muscles of swallowing, and difficulty of speech. Respiratory paralysis is the usual cause of death.

c. Source of the Toxin. Sources of the toxin are the bacteria *Clostridium botulinum* and *Cl. parabotulinum,* which are rod-shaped, slightly motile, sporulating, gram-positive, anaerobic bacilli. The principal reservoir of the bacteria is soil. The bacteria grow and form their toxin under anaerobic conditions, usually in improperly canned,

nonacid foods such as meats; sausage; and some vegetables, including corn, string beans, spinach, and olives.

d. Mode of Transmission. Transmission is through eating of food contaminated with botulinum toxin. The bacteria do not grow or reproduce in the human body, and poisoning is due entirely to the toxin already formed in the ingested material. Fresh foods are not involved; freshly well-cooked foods are not involved, as heating destroys the toxin. Possibly the toxin could be introduced through breaks in the skin or by inhalation.

e. Latent Period. Symptoms of poisoning usually do not appear until between 12 and 72 hours after food containing the preformed toxin has been consumed, the length of time depending upon the amount of toxin contained in the consumed food.

f. Susceptibility and Resistance. All persons are susceptible to poisoning. The few who recover from the disease have an active immunity of uncertain duration and degree.

g. Prevalence. The disease has world-wide distribution; it is prevalent wherever improperly canned food products are consumed.

h. Mortality. Mortality is approximately 65 percent in the United States but is low in Europe; it is directly related to the amount of toxin consumed.

i. Immunization. Passive immunization with antitoxin appears to be encouraging as a protective measure for humans but is of little therapeutic value. Active immunization with botulinum toxoid is of proved protective value.

j. Treatment. Treatment is mainly supportive. Antitoxin therapy is of doubtful value, particularly where large doses of the poison have been consumed.

k. Epidemicity. The disease is not contagious. Epidemics occur only where widespread distribution and consumption of a contaminated food product have occurred.

l. Stability. The toxin is stable for a week in nonmoving water where it is not aerated. It persists for a long time in food when it is not exposed to air. The toxin is destroyed when boiled for 15 minutes, but botulinum spores resist boiling for 6 hours. Pressure cooking will destroy the spores. Botulinum toxin differs from other bacterial toxins in that it is not destroyed by gastrointestinal secretions.

77. Staphylococcus Toxin

a. Description. The toxin is produced in food by certain strains of staphylococci. It is an enterotoxin, since it has a specific action on the cells of the intestinal mucosa. Unlike most bacterial exotoxins, it is

stable at boiling temperature and antigenically is irregular in eliciting the formation of immune bodies.

b. Disease Produced. A food poisoning (not infection) is produced following the ingestion of food in which various strains of staphylococci have been growing. It is usually characterized by sudden, sometimes violent onset, with severe nausea, vomiting stomach cramps, severe diarrhea, and prostration. Patients usually feel normal 24 hours after the attack begins.

c. Source of Poisoning. The source of contamination is not known in most cases but is probably of human origin. Food implicated as sources of food poisoning are chiefly pastries (creamy), milk (raw) and milk products, and meat. Food handlers who are nasal or skin carriers of pathogenic staphylococci or who have an open staphylococcal lesion on hands, arms, or face have been traced as sources of poisoning. The implicated foods usually are allowed to remain at a warm temperature before consumption, thus providing an incubation period for formation of toxin.

d. Mode of Transmission. Consumption of contaminated custard-filled pastry; processed meats, particularly ham; and perhaps milk from cows with infected udders are modes of transmission. Improper food handling is responsible for many outbreaks.

e. Latent Period. Incubation is relatively short. One-half hour to 4 hours, usually 2 to 4 hours, elapse between taking of food and appearance of symptoms.

f. Susceptibility and Resistance. Most persons are susceptible, but individual reactions are variable.

g. Prevalence. The toxin is world-wide and is probably the principal cause of acute "food poisoning."

h. Mortality. Fatalities are rare.

i. Immunization. There is no immunization.

j. Treatment. Treatment is supportive.

k. Epidemicity. Food poisoning is noncontagious. Most outbreaks are small and are confined to persons who have eaten the same contaminated food.

l. Stability. The toxin is resistant to freezing, to boiling for 30 minutes, and to potable quantities of chlorine. The organisms remain viable after 67 days of refrigeration.

CHAPTER 5
POSSIBLE ANTIANIMAL BW AGENTS

Section I. GENERAL

78. Objectives

Antianimal BW agents are those which could be employed directly against domestic food and draft animals to injure, incapacitate, or destroy them through disease. The indirect but main purpose of their use is to attack man by limiting his food supply. Other important losses might be damage to his animal transportation facilities and lessened output of hides, wool, fats, and biological medicinal products (adrenalin, insulin, pituitary extracts, ACTH, and liver extracts).

79. Targets

The main animal targets would be cattle, swine, sheep, goats, horses and mules, and fowl. It is known that epidemics of the animal population, known as epizootics, occur more readily than do epidemics among man because most of the animal agents are readily transmitted from one animal to another, or from herd to herd, by direct contact; by contact with contaminated food, water, and excreta; or by exposure to aerosols (coughing or sneezing). It is therefore reasonable to assume that it would not be difficult for any enemy to produce epizootics by disseminating relatively large amounts of infective material from aircraft or small amounts secretly by saboteurs and spies, either before or after the beginning of open hostilities.

80. Types

It is probable that more kinds of animals have tuberculosis, a bacterial infection, than any other single disease. However, the virus diseases are probably more serious for animals than are those caused by all other classes of micro-organisms. Prevalent animal virus diseases are rinderpest (cattle, sheep, goats); foot-and-mouth disease (cattle, sheep, swine, and other cloven-footed animals); Rift Valley fever (sheep, man); hog cholera; African swine fever (wart hog disease); bovine viral diarrhea (cattle); fowl plague; Newcastle disease (fowl); equine encephalomyelitis (horses, man); vesicular exanthema (swine); and vesicular stomatitis (horses, mules, cattle). Notable bacterial diseases are anthrax (sheep, cattle, man); brucellosis (cattle, swine, goats, man); and glanders (horses, man). Rickettsial diseases of domestic animals are rare, exceptions being the tick-borne "heartwater" or veldt disease, which has a high mortality in cattle, sheep, and goats in South Africa; psittacosis (birds, man); and Q fever in cattle and

sheep in the United States. Fungus diseases of animals do not seem to offer important BW possibilities, although some are quite destructive. Serious protozoan diseases of animals are rare, except for trypanosome diseases of horses and cattle, and *Babesia* infections (babesiosis) of cattle, horses, and sheep. Botulinum toxin will poison certain animals and birds, but only exceptionally is it produced under natural conditions, as occasionally in the sediment of ponds, where ducks have been killed after consuming infected material. Pests, although annoying and often highly debilitating to domestic animals, are not promising antianimal BW agents, except as vectors of disease. Properties of some agents which might be considered to offer possibilities in antianimal BW are presented in paragraphs 81 through 93.

Section II. BACTERIA

81. Bacillus Anthracis

a. General. This organism and the infection it produces in man have been described in paragraph 48 under antipersonnel agents. The discussion which follows will be limited to considerations of its pathogenicity for animals.

b. Disease Produced. Anthrax, also known as charbon or splenic fever, is principally a disease of herbivorous animals (cattle, sheep, horses, and mules), although occasionally it affects hogs, dogs, cats, and some wild animals. Sheep are the most susceptible domestic animals, followed by cattle. In animals, anthrax occurs as an acute febrile septicemic infection characterized by depression; weakness; difficult breathing; inflamed mucous membranes; bloody diarrhea; and swellings in the neck, chest, flank, and lumbar regions. The spleen becomes enlarged and may in some cases be so distended that its capsule ruptures; there is marked liver damage. The intestinal tract is inflamed and hemorrhagic; the lungs are congested; and the lymph glands are swollen, congested, and hemorrhagic.

c. Sources of Infection. Contaminated soil, food, water, flies, and dust are sources of infection. Scavengers such as buzzards may distribute infected material by feeding upon carcasses and vomiting the material at other locations.

d. Mode of Transmission. Normally, transmission is made by ingestion of contaminated food and water; through wounds or scratches; by inhalation; and mechanically by flies, ticks, and birds.

e. Incubation Period. Incubation is from 3 to 7 days.

f. Susceptibility and Resistance. Sheep are very susceptible, cattle somewhat less so, with the horse and mule intermediate; hogs have fair resistance (although serious outbreaks have occurred among them), while birds and fowl are practically immune.

g. Prevalence. Anthrax is prevalent wherever herbivorous domestic animals are raised (world-wide). It is particularly prevalent in countries where no organized control of animal diseases exists.

h. Mortality. Mortality is very high, probably from 40 to 80 percent in affected animals.

i. Immunization. Attenuated spore vaccines are effective immunizing agents.

j. Treatment. Penicillin and sulfathiazole may be used. Antianthrax serum used promptly in large doses is effective.

k. Epidemicity. The disease has moderate communicability; once the disease is established, it often builds up to epizootic proportions. Control measures include strict quarantine of infected areas, observation and immunization of exposed animals, prompt decontamination of discharges and areas inhabited by infected animals, and proper disposal of carcasses.

l. Stability. See paragraph 48*l* for stability.

82. Brucella Group

a. General. The organisms of this group, *Br. abortus*, *Br. melitensis*, and *Br. suis*, have been described in paragraph 50 under antipersonnel agents. The following discussion is limited to those aspects which are concerned with pathogenicity for animals.

b. Disease Produced. The three closely related species of *Brucella* produce the disease known as brucellosis, which is sometimes given different names associated with each of the causative organisms.

(1) *Brucella abortus* is the most common cause of this disease in animals. The disease was formerly known as Bang's disease and is also known as contagious abortion and bovine brucellosis. It is one of the most important diseases of livestock from an economic viewpoint. It is mainly a disease of bovine animals (cattle, oxen), but other animals, including horses, sheep, goats, swine, and dogs, are susceptible to a lesser extent. The organism can also cause brucellosis in man. The disease may exist and persist in the genital system of the bull without evident symptoms. In pregnant cows it is characterized by a chronic inflammation of the uterus (especially of the mucous membrane), which is usually, but not invariably, followed by abortion between the fifth and eighth months of pregnancy. In cases of abortion, a placentitis is produced which is serious not only because it endangers the life of the fetus but also because it results in injury to the uterus that may affect future pregnancies and also render the cow susceptible to secondary infection. When nonpregnant cows become infected, there are

usually few recognizable symptoms to indicate that they have the disease. Infection may occur by the mouth, through the vagina during service, after a bull has serviced an infected cow or when the bull is a carrier, or by other means (*d* below). This disease presents a serious carrier problem, as a large percentage of infected cows may harbor the organism in their udders for as long as 7 years.

(2) *Brucella melitensis* produces a chronic disease which is also known as Malta fever, Mediterranean fever, and contagious abortion in animals and undulant fever in man. This organism is closely allied to *Br. abortus* and gains entrance into the body mainly through contaminated food. Goats are the natural or true hosts for this organism. Sheep are next in susceptibility, followed by cattle, horses, and swine. This species is more pathogenic for man than the other two. Affected goats and sheep develop a moderate, remittent, long-continued infection which may escape notice. They may appear in poor condition, and a chronic inflammation of the udder may be present in severe cases, but it is not until late in the disease that the milk undergoes any noticeable change or milk secretion diminishes. A chronic cough is sometimes present, and 50 to 90 percent of pregnant females may abort. Lameness may occur in both males and females. The disease is rarely fatal, but its importance lies in the possible transmission to man, where symptoms are much more serious. It does present a serious carrier problem, because large percentages of apparently healthy animals are carriers, with the organism being present in the udder and blood and frequently eliminated in the milk and urine.

(3) *Brucella suis* causes brucellosis of swine and is also pathogenic for man and, occasionally, for horses, dogs, and cows. The disease in swine resembles that of both man and cattle. As with the other forms, it can result in contagious abortion, although this does not always result; that is, abortion is not the disease but rather a symptom that is sometimes observed. The organism is said to be more virulent for man than *Br. abortus* and less so than *Br. melitensis*.

c. Sources of Infection. The tissues, blood, milk, and urine of infected animals, especially goats, cattle, and swine, are sources of infection.

d. Mode of Transmission. Transmission is made by ingestion of milk, food, and water contaminated with the organism; inhalation of infected dust from contaminated pens and forage; skin infection from direct contact; and by mating in cattle.

e. Incubation Period. Incubation is variable, depending on the strain of organism, the kind of animal, and the route of infection.

f. Susceptibility and Resistance. Susceptibility of animal species to different strains is variable and has been considered above. Animals that recover from the disease usually are highly resistant to reinfection; however, some may be reinfected.

g. Prevalence. The disease is world-wide, particularly in areas having a high population of cattle, sheep, goats, and swine.

h. Mortality. Mortality is very low.

i. Immunization. Vaccines are in general use for cattle. The measure most widely used is calfhood vaccination with a *Br. abortus* strain of reduced virulence, known as BAI strain 19.

j. Treatment. Antibiotics and sulfonamides appear promising, but there is no really effective treatment.

k. Epidemicity. Epizootics are common in herds and flocks. Methods of control consist of testing, segregation, and slaughter of infected animals, as the disease is readily transmitted from animal to animal.

l. Stability. See paragraph 50*l* for stability.

83. Malleomyces Mallei

a. General. This organism and the disease it produces in man have been discussed in paragraph 55. The following discussion is limited to those aspects concerned with its pathogenicity for animals.

b. Disease Produced. Glanders or farcy (cataneous) is an acute or chronic disease of equines (horses, mules, asses), communicable to dogs, cats, goats, sheep, and man. It does not occur in cattle and swine. Definite symptoms of lobular pneumonia or bronchopneumonia are often present in the early stages of the acute form of the disease; however, irrespective of the form of the disease, lesions of the spleen and liver often occur.

(1) The acute form is limited to mucous membranes of the nose and upper respiratory tract. It is characterized by fever and prostration, nasal discharge, ulceration of the nasal mucosa, and acute swelling of the lymph nodes, which may break down and form deep, pus-discharging ulcers and sinuses. The acute disease is usually fatal, death occurring within 4 to 6 weeks.

(2) The chronic form has a more gradual onset than the acute form and is characterized by formation of persistent abscesses, arthritis, ulceration of the nostrils, multiple skin swellings, ulcers, and nodules and by general enlargement of the regional lymph glands. Cutaneous glanders (farcy) is usually chronic.

c. Source of Infection. Infected animals and contaminated food and water are sources of infection.

d. Mode of Transmission. Transmission is by ingestion of contaminated food and water, by direct contact with infected animals (through skin abrasions), and by inhalation of infected material.

e. Incubation Period. Incubation is from 2 to 5 days, occasionally 2 to 3 weeks.

f. Susceptibility and Resistance. Equines are the most susceptible animals. Recovery from the disease does not confer immunity.

g. Prevalence. The disease is most prevalent in parts of Europe, eastern and southern Asia, and northern Africa. Introduction of the disease must always be guarded against whenever an animal is brought into the herd from an external source.

h. Mortality. Acute glanders usually is fatal. The chronic form has a mortality of 50 to 70 percent.

i. Immunization. Immunization is very unsatisfactory.

j. Treatment. Treatment is unsatisfactory at the present time. Sulfadiazine and streptomycin may be of some value against the chronic form. Radical surgery is usually preferred in chronic cases. (The law in most civilized countries does not permit any form of treatment being tried, because all diagnosed cases must be destroyed as soon as possible.)

k. Epidemicity. Epizootics may occur where large numbers of animals are herded together; where sanitary requirements for stabling, feeding, and watering are lax; and where diagnostic procedures are inadequate.

l. Stability. See paragraph 55*l* for stability.

Section III. VIRUSES

84. Foot-and-Mouth Disease Virus

a. Description. This is a very small virus which is 8 to 12 millimicrons in diameter. Six types of the virus have been recognized.

b. Disease Produced. Foot-and-mouth disease, also known as aphthous fever, is an acute, contagious, highly infectious, febrile disease of cloven-footed animals (cattle, sheep, swine). Man is only slightly susceptible and, if infected, shows only mild symptoms. The disease causes a marked and rapid weight loss, a rapid decrease in milk flow, and a severely lowered reproductive capacity. It is characterized by an acute fever and by vesicle formation on the feet and mucous surfaces of the mouth and cheeks and on the udder. In most cases, a long time elapses before the animals return to normal.

c. Source of Infection. Infected animals and contaminated food, water, milk, and pastures are the sources of infection.

d. Mode of Transmission. Transmission is by ingestion of food, water, and milk contaminated with urine, saliva, vesicular fluid, and feces and by direct contact.

e. Incubation Period. Incubation is usually from 24 hours to 7 days, occasionally 2 or 3 weeks.

f. Susceptibility and Resistance. Cloven-footed animals have a susceptibility of from 80 to 100 percent.

g. Prevalence. The disease is enzootic in various parts of Europe, Asia, Africa, and South America; recent epizootics occurred in Mexico and Canada. The last outbreak in the United States was in 1929.

h. Mortality. While the mortality in mild cattle epizootics is said to range from 3 to 5 percent, malignant forms have caused a mortality as high as 50 to 70 percent. The mortality for sheep is around 5 percent and for swine is from 50 to 70 percent.

i. Immunization. Vaccines are effective in developing an active immunity, but each vaccine is specific only against the strain from which it was made. Promising strides in the development and production of vaccines have been made in very recent years.

j. Treatment. Treatment is supportive only.

k. Epidemicity. The disease has very high communicability. It tends to spread rapidly over a wide geographic area. The disease is controlled mainly by quarantine and vaccination of exposed animals and slaughter of infected animals.

l. Stability. The organism is quite resistant under natural conditions. Contaminated hay and bran may remain infective for weeks, and the organism may persist in moist soil for months. It is resistant to low temperatures but is destroyed within 30 minutes at 140° F. or above. It resists drying for several weeks. Two percent sodium hydroxide solution is preferred for decontamination.

85. Rinderpest Virus

a. Description. The virus is very small.

b. Disease Produced. Rinderpest is also known as cattle plague. It is an acute, febrile, highly contagious and highly fatal disease of bovine animals (cattle, oxen), sheep, goats, and water buffaloes. It is characterized by sudden onset, croupous inflammation of the digestive tract, inflammation and erosion of the mucous membranes of the mouth, and bloody diarrhea. The virus is present in practically all of the body tissues and fluids of infected animals.

c. Source of Infection. Infected animals are the sources of infection.

d. Mode of Transmission. Transmission is by ingestion of food and water contaminated with urine, feces, saliva, and eye and nasal secretions and by direct contact.

e. Incubation Period. Incubation is from 3 to 9 days.

f. Susceptibility and Resistance. Cattle, oxen, sheep, goats, and water buffaloes are almost completely susceptible.

g. Prevalence. The disease is world-wide, except for the Western Hemisphere.

h. Mortality. Mortality ranges from 25 to 100 percent.

i. Immunization. Excellent specific vaccines have been produced which induce an active immunity. A good immunizing serum can be prepared which confers a passive immunity of short duration. Recovery from the disease is followed by an immunity of indefinite duration.

j. Treatment. Massive doses of antiserum may be used to protect susceptible animals but are of little value after symptoms have appeared.

k. Epidemicity. Epidemicity is very high in nonimmunized animals, as the disease is highly infective, is easily transmitted from animal to animal, and tends to spread gradually over wide areas.

l. Stability. The virus will survive for nearly 3 months under controlled optimum conditions. Exposure to 140° F. kills it within a few minutes. It will resist drying and sunlight for only a few days but when frozen and then dried will remain viable for months. Effective disinfectants are 2 to 5 percent phenol and 0.1 percent bichloride of mercury.

86. Rift Valley Fever Virus

a. Description. The virus is 23 to 35 millimicrons in size and will pass through most filters.

b. Disease Produced. Rift Valley fever, or enzootic hepatitis, is a highly infective and fatal disease of sheep. Goats and cattle are sometimes affected, and the disease is easily transmitted to man, in whom it usually takes a mild form. In sheep, the infection is characterized by rapid course, high fever, loss of appetite, and progressive weakness; it may produce abortion in pregnant females. The disease is more severe in lambs than in the older animals.

c. Source of Infection. Infected animals are the sources of infection.

d. Mode of Transmission. The disease is transmitted by the bites of mosquitoes and possibly by inhalation of infected dust.

e. Incubation Period. Incubation is from 1 to 4 days for adult animals, 12 to 24 hours for lambs.

f. Susceptibility and Resistance. Sheep are highly susceptible, while goats, cattle, and man are less so. Mice, rats, cats, and apes are re-

ported to be susceptible, while horses, rabbits, guinea pigs, and birds seem to be immune.

g. Prevalence. The disease is found in southern Africa, particularly in Kenya colony of British East Africa.

h. Mortality. Mortality is 90 to 95 percent in lambs, 35 to 45 percent in adult sheep, and 5 to 20 percent in cattle.

i. Immunization. A living virus vaccine is in use in South Africa.

j. Treatment. Treatment is supportive only.

k. Epidemicity. Epidemicity is dependent on the presence of diseased animals and the specific mosquito vector.

l. Stability. The virus is said to be destroyed by exposure to a temperature of 132° F. for 40 minutes.

87. Vesicular Stomatitis Virus

a. Description. The virus is 0.07 to 0.1 micron in size.

b. Disease Produced. Vesicular stomatitis, also known as pseudo foot-and-mouth disease or mouth thrush, is a contagious, weakening, febrile disease, primarily of horses and mules and occasionally of cattle and swine. It is characterized by vesicular eruptions of the mucous membranes, particularly of the mouth. Occasionally, lesions may be found on the feet and udders. This disease has great similarity to foot-and-mouth disease; the main difference is that the horse is not susceptible to foot-and-mouth disease.

c. Source of Infection. Horses, mules, and cattle infected with the disease are sources of infection.

d. Mode of Transmission. Transmission is by ingestion of contaminated food and water and by direct contact.

e. Incubation Period. Incubation is from 2 to 9 days.

f. Susceptibility and Resistance. The percentage of horses and mules estimated to be susceptible is 70 to 100.

g. Prevalence. The disease is probably world-wide. It appears sporadically in the United States.

h. Mortality. Mortality is from 0 to 10 percent.

i. Immunization. Immunization is in the experimental stage only.

j. Treatment. Treatment is unsatisfactory. Treatment is only supportive at the present time.

k. Epidemicity. The disease tends to spread gradually over a limited geographical area.

l. Stability. Contaminated food remains infective over long periods. The organism is resistant to low temperatures. The virus remains viable

in 0.5 percent phenol for 23 days. It is destroyed by 2 percent lye in 1 minute and by 0.05 percent crystal violet. In general, it has much the same resistance as that of the foot-and-mouth disease virus (par. 84*l*).

88. Vesicular Exanthema Virus

a. Description. The virus is 0.07 to 0.1 micron in size.

b. Disease Produced. Vesicular exanthema is a contagious, febrile, weakening disease of swine. It is characterized by the formation of vesicles or lesions in the mouth and nostrils; on the snout, feet, and udders; and around the coronary band. The vesicles produced by this virus are very similar to those produced by foot-and-mouth disease and vesicular stomatitis. Animals become lame and hoofs are sometimes shed. Sows may abort in advanced pregnancy. Cattle, sheep, and guinea pigs are not susceptible to the disease.

c. Source of Infection. Infected swine and uncooked garbage containing pork trimmings are the sources of infection.

d. Mode of Transmission. Transmission is by direct contact, by ingestion of contaminated food and water, and by persons going from farm to farm.

e. Incubation Period. The incubation period is from 2 to 7 days.

f. Susceptibility and Resistance. The infectivity rate ranges from 50 to 100 percent in swine.

g. Prevalence. The disease was first discovered in California in 1932 and apparently remained confined there, although it did spread throughout the state, during the next 20 years. It has since appeared in most of the other states in this country and presents a serious menace to the swine industry.

h. Mortality. The estimated herd mortality is 0 to 5 percent for swine.

i. Immunization. None has been developed to date. Immunity following an attack of the disease is comparatively short.

j. Treatment. Treatment is supportive only.

k. Epidemicity. The disease is controlled to some extent by quarantine and slaughter but probably will not become completely manageable until the practice of feeding raw garbage is stopped.

l. Stability. See paragraph 86*l* for stability.

89. Hog Cholera Virus

a. Description. The virus is 0.03 to 0.035 micron in size.

b. Disease Produced. Hog cholera, known as swine fever in Europe, is a highly acute, contagious, febrile disease of swine. It is usually chronic

in older swine. It is characterized by high fever, yellowish discharges from the eyes, diarrhea, loss of appetite, severe hemorrhages, viremia, and extreme weakness.

c. Source of Infection. Infected swine are the sources of infection.

d. Mode of Transmission. Transmission is by contaminated garbage (infected pork) and through food, water, hog wallows, and pens that have been contaminated from eye and nasal secretions, urine, blood, and feces of infected swine. Aerosol transmission is possible. Hogs that have recovered from the disease are possible carriers.

e. Incubation Period. Incubation is from 5 to 6 days.

f. Susceptibility and Resistance. The percentage of exposed swine that are susceptible is 70 to 100. Animals recovering from the disease have an immunity of uncertain duration. The disease is highly infectious for susceptible swine only.

g. Prevalence. Hog cholera has a world-wide distribution and is the greatest menace with which swine-raisers have had to contend. It is widespread in North America (swine-raising areas of midwestern United States), France, Africa, Germany, and England.

h. Mortality. Fatalities are estimated to be 80 to 90 percent in the United States and Africa. In European countries the death loss is often lower.

i. Immunization. Several excellent active and passive immunization methods have been developed and are available.

j. Treatment. Administration of hyperimmune serum is the best treatment and is moderately effective.

k. Epidemicity. This highly contagious disease spreads rapidly and easily among swine. It tends to spread gradually over a wide geographic area. Control of the disease is by rigid measures of isolation and disinfection whenever an outbreak occurs and by crystal violet vaccine inoculation.

l. Stability. The virus is stable for months at low temperatures. It is destroyed by use of 1 to 2 percent caustic soda, 2 percent cresol for 1 hour, and 5 percent milk of lime and by exposure to 149° F. for 1 hour. It is resistant to phenol and glycerin.

90. African Swine Fever Virus

a. Description. The virus is small and very resistant to environmental changes.

b. Disease Produced. African swine fever, also known as wart hog disease and East African swine fever, is a highly contagious and excessively acute disease of domestic swine. It is characterized by fever, pronounced hemorrhages of the lymphatic glands, the kidneys,

and the mucosa of the alimentary tract, and by marked cyanosis (a patchy or diffuse purplish color) of areas on the skin. Clinically, African swine fever is similar to but more acute than American hog cholera; its immunology is distinct from that of hog cholera.

c. Source of Infection. The bush pig and wart hog harbor the virus but usually do not manifest symptoms. Contact with these wild pigs apparently initiates the disease in domestic swine, and once established it spreads rapidly by contact.

d. Mode of Transmission. The disease is transmitted by contact with urine and feces from infected pigs, feeding of raw garbage, or pigs actually eating carcasses of virus-carying wild pigs; it is mechanically spread by caretakers and others who pass from infected premises without taking proper precautionary measures. It is thought that infection may be transmitted from wart hogs to pigs by an insect vector; however, the vector has not been established. In a few cases where hogs have survived the disease, there is evidence that they may act as carriers for as long as 10 months after recovery.

e. Incubation Period. The incubation period is usually 4 to 7 days when exposure is made by contact with infected pigs.

f. Susceptibility and Resistance. In epidemics the disease may occur in 100 percent of susceptible domestic swine. The disease is of such a highly contagious nature that usually, in a few days after the first case is noticed, the majority of the pigs of a herd become infected. However, it has been noted frequently that the virus coming from the wart hog or wild pig takes some time to attain high virulence; the occurrence of an isolated death being followed a week or so later by one or two more deaths and then, after a further interval, the appearance of many cases with rapid spread.

g. Prevalence. African swine fever is not known to exist outside the African continent. Most of the cases have been confined to East Africa and the Union of South Africa.

h. Mortality. Fatalities range from 95 to 98 percent and may be up to 100 percent.

i. Immunization. Attempts at immunizing swine against this virus have been for the most part unsuccessful. Even pigs that have survived infection are not consistently immune to subsequent exposures. Hog cholera antiserum affords no protection against this disease, although in a few cases it appeared to delay the reaction. Although it has not been proven, it is felt that hyperimmune serum prepared from the virus at any given time might be found to be of no effect in subsequent outbreaks, owing to frequent spontaneous changes in the antigenic character of the virus.

j. Treatment. At present there is no effective treatment for the disease.

k. Epidemicity. The disease is highly contagious. It is prevalent in areas where opportunities exist for cohabitation between wild and domestic hogs. Control of the disease has been successful in East and South Africa by immediate slaughter of all infected and exposed animals, disposal of all carcasses by burning or deep burial, disinfection (usually with lye) of the infected premises, and quarantine of infected areas. Measures to prevent contact of domestic swine with wild pigs have resulted in a marked decrease in the incidence of the disease.

l. Stability. The virus is very stable at low temperatures; it has remained viable after storage in a cold dark room for 6 years. It is killed by sunlight but will remain viable in infected carcasses, food, and water for some length of time.

91. Fowl Plague Virus

a. Description. The virus is small, measuring 0.06 to 0.09 micron.

b. Disease Produced. Fowl plague, also known as fowl pest, is an acute, contagious, highly fatal disease of fowl (particularly chickens and turkeys), characterized by hemorrhages in various tissues of the body, swelling, and blood poisoning.

c. Source of Infection. Infected fowl are sources of infection.

d. Mode of Transmission. Transmission is by ingestion of food, water, and soil contaminated by the blood, urine, feces, and eye and nasal secretions from infected fowl or birds; by infection through wounds; and possibly by blood-sucking insects.

e. Incubation Period. Incubation is from 2 to 7 days; it may be as short as 24 hours.

f. Susceptibility and Resistance. The disease has an infectivity rate of 50 to 80 percent.

g. Prevalence. The disease is probably world-wide but is absent from the United States at the present time. The disease is prevalent at the present time in Egypt and Palestine.

h. Mortality. The mortality rate is very nearly 100 percent.

i. Immunization. No satisfactory method of immunization has been established.

j. Treatment. None has been developed.

k. Epidemicity. The disease is highly contagious. Once the disease is introduced into a flock, it tends to spread rapidly and kills all or nearly all of the flock in a short period of time. Control measures

include rigid quarantine and slaughter and burning of infected fowl. All houses and equipment should be disinfected and the contaminated soil treated with caustic soda.

l. Stability. The virus is stable in dried blood or tissues for many months but is destroyed by exposure to 149° F. for 5 minutes. It is also killed by sunlight in a short time. It survives for 18 days on feathers of birds dying of the disease; it will remain viable for months if kept in a cool, dark place free from air. It is destroyed by 0.1 percent bichloride of mercury in 30 minutes or by 5 percent phenol in 10 minutes.

92. Newcastle Disease Virus

a. Description. The virus is 0.08 to 0.12 micron in size.

b. Disease Produced. Newcastle disease, pseudo-pest of fowl or pneumoencephalitis, is an acute, highly contagious, febrile disease of fowl (chickens, turkeys, and pheasants). The course of the disease is of short duration. It is characterized by severe respiratory and nervous symptoms, including difficult breathing, depression and stupor, twitching of the head and neck, marked weakness, twisted neck, and perhaps paralysis. Egg production is interrupted for weeks.

c. Source of Infection. Infected fowl are sources of infection.

d. Mode of Transmission. Transmission is by direct contact, by ingestion of food and water contaminated with feces, and by inhalation of contaminated dust.

e. Incubation Period. Incubation is usually from 4 to 8 days, although it may be up to 13 days.

f. Susceptibility and Resistance. The infectivity rate ranges from 50 to 90 percent. Chickens of all ages and turkeys are highly susceptible; pigeons, geese, ducks, and other barnyard fowl are less susceptible.

g. Prevalence. The disease is world-wide.

h. Mortality. Fatalities range from 10 to 100 percent. The disease found outside the United States is nearly 100 percent fatal; strains found in the United States and recently in England usually are much less pathogenic.

i. Immunization. Vaccines prepared from live virus of low virulence produce an immunity of a few months' duration; revaccination of layers should be at 12 to 16 weeks of age. Recovery from the disease is accompanied by some immunity.

j. Treatment. None has been developed.

k. Epidemicity. The disease is highly communicable and tends to spread gradually over wide geographic areas. Greatest incidence of the

disease in the United States is in the winter months. Control measures consist of vaccination and maintenance of a high standard of sanitation.

l. Stability. The virus remains viable for years when dried in the frozen state (lyophilized); it is readily destroyed by being heated at 72° F. (pasteurization). Highly effective disinfectants are 3 percent phenol, 3 percent cresol, and 2 percent sodium hydroxide solutions.

93. Equine Encephalomyelitis Viruses

a. General. There are several viruses, each specific for the different forms of the disease, which include Eastern and Western equine encephalomyelitis and Venezuelan equine encephalomyelitis. These viruses are also pathogenic for man, with high mortality rates. The disease in man has been described in paragraph 67, and the information below relates only to the infection which occurs in animals, mainly equines. In appearance the organisms are similar, being small, neurotropic viruses.

b. Disease Produced. Equine encephalomyelitis (sleeping sickness) is an acute infectious disease of the central nervous system of horses and mules (also of man). It is characterized by fever, drowsiness or restlessness, incoordination, and occasionally convulsions; in the severe cases motor and sensory paralysis cause prostration, and death results from respiratory and cardiac failure.

c. Source of Infection. Birds, and probably many wild and domestic animals, may become infected and serve as temporary reservoirs for the virus. The organism probably has a wider host range than any other pathogenic agent.

d. Mode of Transmission. The infection is transmitted by blood-sucking arthropods (usually mosquitoes) and perhaps by ticks, from the animal reservoirs mentioned in *c* above to horses, mules, and man. Transmission may be by contact with nasal secretions of infected horses.

e. Incubation Period. Incubation is from 1 to 3 weeks.

f. Susceptibility and Resistance. Laboratory investigations indicate that many animals other than the equines are susceptible to the disease. Susceptibility of a herd may be as high as 80 percent, but this varies with the kind of virus and the type of animal. Recovered animals appear to have a substantial immunity to the disease.

g. Prevalence. The disease occurs in the summer and early fall. Eastern and Western types are found in Canada, the United States, and Central and South America; the Venezuelan type is found in Venezuela, Colombia, and Trinidad.

h. Mortality. Fatalities range from 27 percent in the Western type to about 90 percent in the Eastern type.

i. Immunization. A very effective vaccine is available for producing active protective immunization in horses. Passive immunity can also be conferred by injection of hyperimmune serum.

j. Treatment. Treatment with immune serum is of great value if given before cardinal symptoms are present or in the very early stages; however, it is of little value when administered after symptoms appear. Sulfonamides and penicillin are ineffective; good nursing care and supportive treatment are very important.

k. Epidemicity. The disease tends to spread rapidly over local areas when insect vectors are present.

l. Stability. The virus is inactivated by being heated at 140° F. for 30 minutes; it is readily destroyed by formalin, bichloride of mercury, chloroform, and ether. It is quite resistant to glycerin and phenol and to low temperatures.

CHAPTER 6
POSSIBLE ANTICROP BW AGENTS

Section I. GENERAL

94. Objectives

Anticrop agents are living or nonliving substances which can be used to injure or destroy food, feed, fiber, oil, medicinal, or industrial crops. They comprise micro-organisms, pests, and chemical contact herbicides and plant growth regulators. The micro-organisms achieve their results by producing disease; the pests cause mechanical injury by biting, sucking, and boring and also act as vectors of disease agents. The chemical compounds achieve their results by systemic physiological action or local tissue damage. With the exception of the contact herbicides and growth regulators, which are killing agents, the anticrop agents generally exert their action to reduce crop yields rather than to destroy the plants outright. The indirect objects of an anticrop attack are man and his economy or ability to wage war; these objects are accomplished by limitation of food supply and destruction of industrial crops, such as cotton, rubber, and lumber.

95. Targets

a. Anticrop agent targets may be living plants, shrubs, and trees or the food or industrial crops produced by them. Food plant crops of importance would include potatoes, sugar beets, truck garden vegetables, soybeans, millet, sorghum, rice, corn, wheat and other cereals, and tree fruits; industrial crops of great importance are cotton, potatoes, rubber, hemp, and lumber. Selection of targets would, to a great part, be determined by their relative importance in the national economy.

b. Plant disease agents that attack the basic food crops, such as the cereals (wheat and rice), potatoes, or others according to their regional use, would be of greatest concern. Epiphytotics in the chief centers of production could cause scarcity, with serious national and international consequences. For example, the late blight of potato had a decided influence in the defeat of Germany in World War I in that it destroyed about a third of the potato crop, which made up a large part of the wartime diet of the Germans; this caused a reduction in the already scanty food supply, which contributed to the breakdown in morale and physical endurance. Plant diseases can cause or aggravate serious shortages in wartime, for during this time fewer varieties of crops are likely to be grown; their products are urgently needed in greater quantities than usual; replacements or substitutes are hard to get or are unsatisfactory; diversion of chemicals necessary in the manufacture of fertilizers and

fungicides to other use hampers control of parasitic and nonparasitic diseases; and the overloaded transportation facilities multiply the effects of all other factors.

96. Types

Among the micro-organisms, a great majority of serious plant diseases are caused by pathogenic fungi. Included among them are the various cereal stem-rust diseases, late blight of potato, rice blast, Southern blight of root crops, and smuts. The fungal agents, by virtue of their ability to form spores in large numbers which are stable upon drying and easily windborne or spread by insect vectors, are potentially quite dangerous as originators of epiphytotics or plant disease epidemics. In addition, fungi can initiate infections easily, as their spores and filaments can invade not only through natural openings in the leaves but also through the intact surface of the epidermis of leaves and roots. The next most important microbic anticrop agents are the bacteria and viruses. The bacteria may attack the conducting tissues of plants and interfere with water movement so that they wilt or invade soft tissues of leaves and roots and cause rotting or produce galls. Viruses are usually spread by insect vectors or by contact and produce systemic effects; most crop plants are subject to attack by one or more virus diseases. Bacterial wilts of corn and cucumbers are widespread, as are the tobacco and cucumber mosaic virus diseases and curly top virus disease of beets. The chemical growth regulators are particularly damaging to broadleaf crops and are but slightly affected by environmental conditions; newer type plant growth regulators are also effective against cereal crops such as rice, millet, wheat, and rye. There are a large number of pests, such as the Japanese beetle, Colorado potato beetle, Mexican bean beetle, and grasshopper, which cause great damage; however, their slowness of action might limit their use as BW agents.

Section II. PLANT PATHOGENS

97. Phytophthora Infestants (Late Blight of Potato)

This fungal organism attacks potatoes and tomatoes and produces large water-soaked lesions on the foliage. At high humidity the undersurface of these lesions is covered with a fine, white, moldlike sporulation. The destruction of foliage by the fungus reduces the crop; the spores reaching the tubers will cause tuber-rot which may destroy the remainder of the crop. Natural epiphytotics may cause crop reductions of 50 to 100 percent. For example, this disease was responsible for the Irish famine in the middle of the nineteenth century, when it destroyed the potato crop on which these people were almost wholly dependent. The outbreak of this disease in Ireland was part of a pandemic that simultaneously spread out into several European countries

and into the United States. Late blight requires moisture for several hours for spore germination and penetration. Moist, cool nights, with the temperature around 60° F. favor penetration, while warmer days at about 75° F. speed development of the lesions, which occur in from 5 to 7 days. The spores may be wind-borne for short distances, possibly as much as 1 mile. With favorable conditions of high moisture and warm weather, the complete destruction of a large field of potatoes could result from a single spore after 3 to 4 generations of spread of 1 week each. The spores are oval, thin-walled, hyaline, and from 21 to 38 by 12 to 23 microns in size. Normally, the disease is initiated from infected seed stock, infected southern grown tomato plants, and blighted tubers from piles of discarded potatoes of the previous year. Control measures are sanitation, protection, and use of resistant varieties. Chemical control measures, consisting of spraying at 7- to 10-day intervals, are satisfactory but are costly in time, machinery, and materials. Resistant varieties are being developed both in North America and in Europe, but there is no known variety that is resistant to all strains of the blight fungus.

98. Helminthosporium Oryzae (Brown Spot of Rice)

This is a fungal organism, causing the disease known as brown spot of rice which has an apparently world-wide distribution. The most common natural source of infection is infected straw from rice refuse, although certain weeds provide a reservoir of infection. The organism will survive through winter and can withstand very low temperatures. Infection is initiated either by the spores or by mycelial fragments, the spores being much more infective. The organism requires high humidity, free water on the leaves, and a temperature range of 69° to 86° F. to produce infection. The incubation period is a matter of days. In very young or seedling plants, it causes seedling blight (damping off); on older plants, it causes leaf and stem lesions; on plants in the heading stage, infections of the kernel are produced. Shriveled and blighted kernels result from the infection, so that crops are reduced or destroyed. Resistant varieties offer the best means of control; sanitation, crop rotation, and seed treatment are ineffective in controlling the disease.

99. Piricularia Oryzae (Blast of Rice)

This organism is a fungus which causes the serious blast disease of rice in Japan and the Orient, particularly in very humid regions. The primary natural source of infection is the mycelium of the organism which lives through the winter in dead rice stubble or weeds. The disease is transmitted by airborne spores, and air temperatures above 70° F. are necessary for infection to occur. The period of incubation, from exposure to appearance of symptoms, is from 4 to 6 days.

Secondary infection from infected to uninfected plant requires an additional 6 to 12 days. High humidity and presence of free moisture on the leaves are necessary for spread of the disease. Rice blast is one of the most important and destructive enemies of rice, causing extensive damage in the early stages of plant development and again in the heading stage. The fungus produces lesions at the bases of the leaf sheaths and in the neck region of the stem, causing the stem to break over, a condition known as "rotten neck." This condition, combined with loss of moisture through the leaf and sheath lesions, reduces grain yields by damaging the developing head, so that the ear is not filled. Yield reductions in epiphytotics are variable, losses of all degrees having been reported.

100. Puccinia Graminis (Stem Rust of Cereals)

This fungus attacks wheat, oats, rye, and barley and many grasses, both wild and cultivated. It has world-wide distribution and includes several strains, each of which is restricted to one host; within the strains many races of different varietal infectivity exist. While the fungus has several spore forms and typically passes from grain to barberry to grain in annual cycles, the spread over large areas is dependent upon the rapid build-up of the red rust or repeating summer spore stage on the cereals. The repeating spores (uredospores) are ellipsoidal, golden brown, and very spiny and show 4 germ spores. They are 13 to 24 by 21 to 42 microns in dimension. In North America this repeating stage overwinters only in the extreme southern parts of the United States and in northern Mexico. The spore falling on a susceptible host germinates, enters, and develops within the host; in from 8 to 12 days an erupted pustule appears, where spores are produced by the many thousands. These are readily dislodged, and each spore is capable of producing a new infection if deposited on a susceptible plant and a moist period (dew or rain) of several hours' duration follows. While most of the new infections will be nearby, a small percentage of spores will reach the upper air currents and drift for many miles. Southerly winds over the Great Plains of the United States afford transport for an annual migration northward each season. In years of high temperatures and moisture in the early spring, early season build-up permits extensive spread throughout the area; losses of greater than 50 percent may result. Pustules, orange red in color, are produced on leaves and stem. They lead to excessive water loss, which is in proportion to the number and size of pustules. The result is a reduced crop and shriveled grain. Control, world-wide, is by developing varieties resistant to the most commonly occurring races. The introduction of new races to an area may lead to destruction of normally resistant varieties and heavy loss until new varieties of grain are

developed. Fungicidal dusts have given satisfactory control in experiments; however, the high cost has not justified the treatment.

101. Puccinia Coronata (Crown Rust of Oats)

This is a rust disease of oats rather similar in life history to the stem rust of grains. However, it is limited to oats and to related wild grasses. It is world-wide in distribution in areas suited to oat production. In the Southern and North Central States of the United States, it is particularly destructive. Many races of this species exist, the races having different varietal infectivity. The alternate host is the common buckthorn; overwintering resting spores infect the buckthorn in the spring, producing more spores which infect oats. The repeating summer spores produced on oats infect other oats with a spread similar to that of stem rust. As with stem rust, the infecting spores originate in the southern areas and a northward migration occurs each season. The buckthorn permits much earlier infection and heavier losses than in localities where the disease is dependent upon wind spread from warmer areas. The organism produces orange-colored pustules on the leaf and stem, resulting in excessive water loss and reduced crop. The damage is heavy in humid seasons when germination of a high percentage of the spores occurs. The losses on oats are usually greater than those caused by stem rust under these conditions and may result in yield reductions of 20 to 50 percent. Control consists of the use of resistant varieties and eradication of the buckthorn to remove the source of very early season infections.

102. Ustilago Maydis (Smut of Corn)

This organism is a sporulating fungus which causes the disease of maize known as common smut of corn or boil smut. Another species of smut causes heat smut of sorghums and corn, and a little-known form causes kernel smut in Italy and the West Indies. Corn smut is prevalent in North and South America, Europe, and India. The disease is characterized by the production of galls on stems, leaves, axillary buds, ears, and parts of the male flowers. The galls may reach a size of 4 inches or more and change from light-colored to powdery black masses of spores. Depending upon the location of the galls, various pathological changes occur, resulting in various degrees of yield reduction and sometimes bending of the stem. In young plants, gall formation may result in extreme dwarfing or death of the plant. The disease spreads mainly by airborne and waterborne spores and sometimes by contaminated seed; the spores also persist on crop refuse and in the soil. The period between infection and formation of galls varies from 1 to 3 weeks, depending on environmental conditions. Infection occurs very largely either during cloudy or moist days or on dewy nights. The spores may remain viable for several years. They are only slightly

injured by freezing. Control of the disease is practicable only through planting of resistant varieties, but crop rotation, destruction of smutted ears or stalks, and avoidance of smut-contaminated manure are helpful control measures. Corn smut has reduced sweet corn yields in some areas by 60 percent, and field corn losses may range from 2 to 15 percent or higher.

103. Tobacco Mosaic Virus (Tobacco Mosaic Disease)

This is a virus which attacks tobacco and a great many other solanaceous (nightshade family) plants such as the tomato, as well as such unrelated plants as beets, peppers, turnips, and many others. Typically, it causes a mottling of the leaves with lighter green areas distributed throughout and a certain amount of dwarfing. The amount of leaf wrinkling and distortion varies with the crop and with the strain of the virus. Yields are greatly reduced in many cases. Infected tomatoes produce very few fruits and these are small in size. The virus is readily transmitted by mechanical means, as well as by certain aphids. Handling of the plants in transplanting or rubbing of the leaves by cultivation machinery leads to rapid spread. This virus is resistant to drying and can persist for long periods in dried infected plant parts. It survives the processing of cigarette and pipe tobaccos, and workers smoking tobaccos containing the virus can transmit the disease to plants by handling. This is one of the major causes of the disease in such crops as tobacco and tomato which are transplanted in the seedling stage. Control is difficult. In tobacco, some varieties have a high degree of resistance; in planting crops, it is a matter of crop sanitation to avoid fields or plant beds containing the virus in old plant refuse and to avoid plant contamination from smoking tobacco.

104. Curly Top Virus (Curly Top Disease of Sugar Beets)

This virus causes curly top disease of sugar beets in the arid portions of the United States west of the Rocky Mountains. A very similar disease is found in Argentina. Curly top is characterized by a rolling and distortion of the leaves. Many fibrous roots develop, causing a "woolly" root condition. The yield of roots is low and the sugar content much reduced. In cross-section, the roots show concentric brown rings. The extent of loss varies with the age of the plant at the time of infection, as young seedlings may be killed while much older plants show little loss. Losses of several million dollars per year have been reported. The disease almost destroyed the sugar beet industry in the Western States during 1916 to 1932 and still causes severe injury to tomatoes, beans, and a number of other crops every year. In nature this virus is transmitted only by the beet leafhopper *(Circulifer tenellus)*. This is a type of biological transmission in which the virus is taken into the insect and incubated for several hours before transmission is pos-

sible. The leafhopper may continue to transmit the virus at each feeding for up to 54 days. The disease is latent in the sugar beet for several days before symptoms develop. With a high vector population, the spread is rapid throughout an area. The disease may overwinter in the adult leafhopper, in infected beet plants remaining in the field, and in perennial weeds from which the young leafhoppers may become infected with virus in the spring. The virus does not pass through the insect egg. The leafhopper is favored by arid conditions with low humidity and increases in great numbers under such climatic conditions. Control is by use of recently developed resistant varieties of beets, by early planting of the crop, and by destroying the Russian thistle on which the leafhopper overwinters readily.

105. Xanthomonas Campestris (Black Rot of Crucifers)

This organism is a rod-shaped, motile, nonsporulating bacterium. It causes black rot disease of cultivated and wild crucifers, including cabbage, cauliflower, Chinese cabbage, turnips, and rutabaga, which are damaged severely, and Brussel sprouts, broccoli, kohlrabi, collard, radish, rape, and mustard, which also are hosts. The disease may affect seedlings in the seed bed or may appear only after plants have been transplanted to the field. It occurs in numerous cabbage growing areas of the United States, and its destructive effects have been reported from many other parts of the world, including Europe, the Caribbean area, New Zealand, and the Philippines. Infection of young and old plants occurs mainly through parts above the ground, especially through the leaves. The organism gains entrance through the water pores of the leaf (stomata) and also through lesions, particularly those caused by leaf-eating insects. The incubation period is from 7 to 20 days. The earliest symptom is generally a yellowing of the leaves and blackening of the veins, beginning at the leaf margin or around some insect injury, with progressive development of the stain into the vascular elements of the main stem, from which it spreads rapidly through the whole plant. It tends to block the water channels and causes the leaves to wilt, turn yellow, and dry up. In severe cases, the leaves drop from the plant. Dwarfing is one of the common effects of the disease. A characteristic feature is the blackening of the vascular (water vessel) system, followed by its plugging by the agent, so that fleshy parts of certain crucifers, such as turnips and kohlrabi, are hollowed out. Other effects occur in other members of the crucifer family, such as the cauliflower. An end result is that affected plants are secondarily invaded by other bacteria which cause a destructive soft rot throughout the head. Losses are not confined to the field but may continue during storage. Field losses of 40 to 50 percent are not uncommon and may even reach 90 to 100 percent. Primary infection may occur from contaminated soil, manure, or seed or by insect trans-

mission. Local dissemination is usually by windblown rain, by use of contaminated cultivation implements, or by transplanting of infected plants. Disinfection of seed and crop rotation are important control measures.

106. Corynebacterium Sepedonicum (Ring Rot of Potato)

This is a rod-shaped, nonmotile, nonsporulating bacterium which causes ring rot disease of potato. First observed in Germany early in this century, it was reported in eastern North America by 1931; by 1940, it was widespread over the potato growing areas of this continent and had caused heavy losses. It produces a wilting of the plant with a browning of the vascular portion of the stem. When the stem is cut and squeezed, a milky viscous bacterial exudate flows from these poisoned areas. Infected tubers show a yellowish vascular discoloration. In well-developed infections, the vascular region (the ring one-fourth to one-half inch beneath the surface) disintegrates, and when the outer portion of the tuber is squeezed, it separates from the pith at the ring in the vascular region. In still more advanced stages, cavities may be formed in the tuber. The organism survives the winter in infected seed potatoes and in dried bacterial slime on crates, bags, buildings, and machinery. It is spread extensively by contaminated knives used in cutting the seed potatoes. Control consists of rigid inspection of seed sources and thorough disinfection of contaminated warehouses, all containers, and potato handling machinery. Precautions in cutting seed potatoes involve the use of rotary knives which are disinfected in mercuric chloride after each cut, By rigid control measures, it is possible to hold the disease to a minimum.

Section III. INSECTS AND OTHER PESTS

107. Popillia Japonica (Japanese Beetle)

This is a metallic green or greenish-bronze insect, one-third to five-eighths of an inch long, with reddish wing covers; it has two prominent and several smaller, white spots near the tip of the abdomen and along the sides. It feeds mainly on the surface of fruits and leaves of deciduous fruits, and grass is sometimes killed by the feeding of the larvae on the roots. This beetle was accidentally imported from Japan to New Jersey about 1916, probably on the roots of nursery stock, and is now widely established from New York to Virginia and west to the Ohio River, occurring also in limited areas of the Southeast. In causes serious injury to tree fruits, many field crops, and some truck crops. Included among its victims are nearly all small and deciduous fruits, shade trees, shrubs, corn, soybeans, garden flowers, vegetables, lawns, grass roots, nursery stock, and weeds. It passes the winter as a grub buried in the soil, completes its growth in June, and emerges in great

numbers in July. The females then lay their eggs in the soil, and grubs develop from them, feeding on decaying vegetation at first, then on the roots of grasses and plants; grubs remain underground until they emerge the following July. The adults fly and feed actively during July and August, particularly on warm, sunny days. Control measures consist of trapping the beetles, spraying and dusting with appropriate insecticides, and inoculation of the soil with a suspension of bacterial spores which causes the so-called milky white disease of the grubs.

108. Epilachna Verivestis (Mexican Bean Beetle)

This insect is a very convex, yellow to coppery brown beetle, one-quarter to one-third of an inch in length, with three rows of black spots across the wing covers when the wings are folded and at rest. It resembles the common beneficial lady beetles but is larger than most of these. This insect is distributed over most of the United States and in part of Canada. It feeds chiefly upon all kinds of garden beans and to a lesser extent on cowpeas and soybeans. It overwinters only in the adult stage, on the ground among leaves and other rubbish, and in woodland and hedgerows bordering fields where beans are grown. The beetle appears about the time that the earliest beans are coming up from seed and for a couple of months later. After the female feeds on the bean leaves, she deposits her eggs in masses on the underside of the leaves. The eggs hatch in 5 to 14 days, and the larvae feed on the leaves for 2 to 5 weeks, during which time they develop into full-grown adults and lay more eggs within 2 weeks for the second generation. About 1 month is required for development from egg to adult, and there may be 3 or 4 generations within one season. This insect causes great economic losses in the bean crop. In attempting to control this pest by spraying or dusting with insecticides, applications should be applied every 10 days so as to cover the underside of the leaves. Quick-maturing varieties will sustain less injury than normal maturing varieties, since damage by this pest occurs mostly during July and August. Rotenone dusts are useful for control.

109. Leptinotarsa Decemlineata (Colorado Potato Beetle)

This common yellow and black-striped potato bug is perhaps the best known beetle in America and is also a pest in Europe. The potato is its favorite food, but it also attacks tomatoes, eggplant, tobacco, peppers, cabbage, and many other plants when the potato is not available. It feeds on the leaves and terminal growth and, unless killed by stomach poisons, quickly devours so much of the vines that the plants die and development of tubers is prevented. Untreated infestations will kill up to 100 percent of the plants. Yields are greatly reduced. The adult lives through the winter buried in the soil to a depth of several inches, emerging in the spring to lay eggs on the undersides of leaves of young

potato plants. These eggs develop into small, reddish, chewing larvae which grow fast and reach the adult stage in 2 or 3 weeks. The potentialities for spread of this insect are enhanced by the ability of the female to lay about 500 eggs in one season. Control measures against this pest consist mainly of spraying or dusting with appropriate insecticides.

110. Anthonomus Grandis (Cotton Boll Weevil)

The adult weevil is a small hard-shelled beetle, about one-quarter inch long, of yellowish, grayish, or brownish color, becoming nearly black as it grows older. It has a slender snout half as long as its body. It is probably the most notorious insect pest in the world, causing annual losses of 20 to 40 percent in the cotton crop, which amount to perhaps $200,000,000, thus increasing the cost of cotton goods to the consumer. The injury is caused by both the adult weevils and their grubs. The adults chew into the squares and bolls with their long snouts to feed on the tissues inside and lay their eggs in the holes. This causes some of the squares and bolls to drop off or wither and die. Grubs hatching from the eggs feed inside the squares and bolls, destroying the flower so that it fails to bloom or develops seeds with little fiber (cotton). The boll weevil winters in the adult stage in all kinds of shelter, such as under leaves and loose bark, in woods, and along fences. The adults straggle out of hibernation from March to June, feeding at first on the tender terminal growth of the plants, then later on the squares and bolls, where the female lays its eggs, 100 to 300 in number. The egg hatches in 3 days into a grub or larva, which, remaining in the boll, feeds and transforms to the pupal stage in 1 to 2 weeks. The pupal stage lasts 3 to 5 days more, when the final change is made to the adult form. The adults then emerge, mate, and lay eggs for another generation. Since the life cycle lasts only 15 to 25 days, there may be from 2 to 10 generations a year. Control is difficult, because in its early stages the insect remains protected in the boll. Control is attempted by fall destruction of infested plants in the field by burning or plowing under, planting early crops, and dust poisoning with insecticides.

111. Locustidae, Order Orthoptera (Grasshoppers or Locusts)

There are many species of this insect, which occur over the whole world. The members of the different species vary greatly in size and color; in any part of the world where these insects abound, man has a difficult time defending his crops. Since ancient times millions of people have died from starvation caused by destruction of crops by hordes of these insects. Damage is most severe where the annual rainfall is less than 25 inches. The most destructive grasshoppers in the United States are red-legged grasshoppers (for legumes such as soy-

beans), the Rocky Mountain grasshopper (for all cultivated crops and grasses), the clear-winged grasshopper (for all cultivated crops), and the Carolina grasshopper. Grasshoppers which attack corn pass the winter in the egg stage below the surface of the ground, hatching from May to July and August, the adults feeding until the first heavy frost. The species destructive in any given year vary with the locality, latitude, weather conditions, and kinds of crops. Control methods consist of fall plowing, to expose the eggs to winter and to birds, and the use of poisoned baits of various types.

112. Phytophaga Destructor (Hessian Fly)

This insect is a small two-winged fly, less than one-eighth of an inch long, of a sooty black color; it has spread to all the principal wheat growing areas of the world. It attacks wheat, barley, rye, and certain wild grasses, wheat being the most favored food, while oats are never attacked. Injury is caused entirely by the larvae, or maggots, which are found from December to March behind the sheaths of the lower leaves of the plant, usually below the surface of the ground, and which withdraw the sap from the lower parts of the stem. Plants which are heavily infested usually die during the winter. Infested plants which have survived through the winter are attacked by the larvae behind the leaf sheaths above the surface of the ground in the spring, and the infested straws break over when the heads of grain begin to fill. From 50 to 75 percent of the straws will fall in a heavily infested field, and the grain yield is seriously reduced. In the spring the larvae develop into the adult fly in a week or two. The flies do not feed, but fly over the fields and mate, the female laying up to 300 eggs. The eggs develop into larvae, which soon go into a "flaxseed" stage that remains through June and July. About August they pupate and the adults emerge to mate and lay eggs. By early October, they reach the flaxseed or overwinter stage in which state they remain until early spring. There are usually 2 generations, although 3 and 4 generations are known in some areas. Infestation of each new crop comes from the stubble of the preceding year. Control measures consist of sowing late in the fall so that wheat will not come up until after the adult flies have emerged, laid their eggs, and died; plowing under infested wheat stubble immediately after harvest; and keeping down all growth of volunteer wheat in the fields or about stacks on which fall generations of flies might deposit their eggs. No insecticide has yet been developed for adequately controlling the Hessian fly.

113. Cirphis Unipuncta (Armyworm)

The larval or caterpillar stage of this insect is a dark green worm, up to 2 inches in length, with white stripes on the sides and down the middle of the back. It attacks all grass crops, particularly corn, timothy,

millet, bluegrass, small grains, and legumes; in epidemics it may destroy most of the vegetation over many hundreds of square miles. When they have consumed the plants in the field where they have hatched, these worms or caterpillars move out in hordes or armies to attack crops in nearby fields. The winter is passed mainly in the larval or worm stage in the soil around grasses or under litter on the ground. The larvae begin feeding early in the spring, are full-grown by late April (in the latitude of Central Illinois), and pupate just below the soil surface. In about 2 weeks they transform into brown or gray moths with a wing spread of about 1½ inches. They hide during the day, fly and mate at night, and then the females each lay 500 or more eggs in the lower leaves of grasses. These hatch into young, pale green worms, which feed mainly at night. Control measures consist of scattering poisoned bait (bran) in the fields where they are feeding or across their line of march or of plowing deep furrows in front of their line of march and then dragging logs through the furrows to crush them. The worm is also preyed upon by a number of insects.

114. Heliothis Armigera (Corn Earworm)

The corn earworm is the larval or caterpillar stage of this insect. Individual worms vary greatly in color from light green or pink to brown or nearly black, being lighter underneath. The body has alternating light and dark lengthwise stripes, the head is yellow and unspotted, and the legs are dark. The insect has a world-wide distribution, producing most severe damage in the South. It is probably the worst pest of corn; it also attacks tomatoes, tobacco, cotton, vetch, and many other plants and weeds. The caterpillar (worm) usually attacks corn through the tip of the ear. The pupal form overwinters 2 to 6 inches below the surface of the ground, the moth emerging in spring and early summer to develop and deposit from 500 to 3,000 eggs on plants on which the larvae feed. The eggs hatch in 2 to 10 days; the worms at first feed on the leaves, then on the corn silk, and later on the kernels at the tip of the ear. When the worms are full-grown, they crawl down the stem and pupate in the ground, coming out as young moths in 10 to 25 days. Thus, there are from 2 to 3 generations of the insect each season, depending on the latitude. It is probable that pupae do not survive the winter north of 40° latitude, northern infestations probably being caused by migration of adults from farther south. At least 2 million acres of corn each year are destroyed in the United States. From 70 to 98 percent of the ears of field corn are attacked during bad years; 5 to 7 percent of the kernels of field corn and 10 to 15 percent of canning corn may be destroyed. No effective measures have been devised to control field corn infestation. Numerous measures are used to protect the smaller areas of sweet or seed corn.

115. Cicadellidae, Order Homoptera (Leafhoppers)

There are many species of leafhoppers. The species vary in size from one-twentieth to one-fourth and rarely one-half inch in length; have long, slender bodies; and vary greatly in color and shape. They are all good jumpers or hoppers. They feed mainly on the under sides of leaves, sucking out the sap, and cause a lack of vigor in the plants attacked. In heavy infestations, affected leaves have a whitened, mottled appearance, and many develop a yellow, red, or brown color. Some species of leafhoppers produce a burning effect by their feeding, causing the tips of leaves to wither and die as if scorched by the sun or injured by drought. Leafhoppers are particularly destructive to clovers in the seedling stage; they also attack alfalfa, many grasses, and small grains. Orchards, vineyards, and forest and shade trees may also be victims. The life cycles vary with different species. Both the nymph and adult forms feed by sucking the sap, and some inject a poisonous substance which kills local areas of tissue around the point of feeding. Some leafhoppers also transmit virus diseases. Control is very difficult. The best method is to cut and remove heavily infested clover and alfalfa crops just after the majority of eggs have been laid. Resistant strains of clover should be planted if available.

116. Nematoda, Phylum Nemathelminthes (Nematodes)

Nematodes, or nemas, are small roundworms, each having a tubular filiform body, mouth, and well developed alimentary canal. They live free in soil or water or as parasites in plants or animals. Plant parasitic nematodes, known as eelworms, occur in enormous numbers in an area where plants on which they can feed exist. They are usually too small to be seen with the naked eye. Full grown nematodes range from less than one sixty-fourth of an inch to one-eighth of an inch in length. Although nematodes reproduce sexually, reproduction without the male is not unusual. The female may lay as many as several thousand eggs during her short life. The life cycle from egg to egg-laying female varies from several days to several weeks, several generations following one another in summer. Cold climate species can easily live through the winter and are not killed by freezing of the soil. Some species may be killed by subjection to drying, while others enter a dormant stage in which they can remain alive for years, being revived in a short time if moistened. (A species parasitic on rye has been revived after 39 years.) Because of these reproductive and survival factors nematodes persist in infected areas as long as a suitable host is present. Several hundred species of nematodes are known to feed on living plants as parasites and to be the cause of a variety of plant diseases. Examples of nematode diseases are "root gall" in grasses, "white tip disease" in

rice, and "root knot" in cotton and similar plants. Almost all plants are susceptible to damage by some species of nematode. Damage to plants is due primarily to the feeding of the nematodes on the plant tissues. The plant nematode has a special feeding organ, known as a stylet or spar, similar to a hypodermic needle, which is hollow and is used to pierce plant tissue or cell walls so that is can suck out the cell contents. Nematodes may enter the plant to feed, or may feed outside the plant or partially embedded in the plant, depending upon the species. Feeding of a nematode may kill the cell or may simply interfere with its normal functioning. If the cell is killed, it is often invaded by bacteria or fungi. Damage to plants is manifested as rotting of the attacked parts and adjacent tissue or development of galls and other abnormal growths. The general appearance of a crop heavily damaged at the roots is that it seems to be suffering from lack of fertilizer and water (stunted growth). The color is a lighter or more yellowish green than normal. Because nematodes usually have an uneven distribution, heavily infected plants may appear next to unaffected or lightly infected plants. Damage to roots, stems, and food-conducting tissues of plants results in yield reductions of 25 to 50 percent. Soil fumigation is the most effective control measure.

117. Achatina Fulica (Giant African Land Snail)

This air-breathing land snail varies from 6 to 10 inches in length and has a shell as big as an orange. It varies in color from soft green, purple, pink, and brown to pure white. Originally a native of Africa, where it is in equilibrium with its environment, it is highly prized by the natives there as a food, and its shell is used as a container for oils or sauces or as a drinking cup. In 1836, the snail was introduced as a curiosity into the Hawaiian Islands; there it has been possible to restrict it to the two islands of Maui and Oahu, where it is a great pest. In 1847, it was taken to India and has since spread to Ceylon, Malaya, Borneo, Sumatra, Java, China, and Formosa. In the first phases of World War II, the Japanese carried it with them to the Southern Pacific islands, where it has caused great damage to vegetation in New Britain, New Guinea, the Philippines, Saipan, Tinian, and the Carolines. The snail is bisexual, or hermaphroditic, having reproductive organs of both sexes. It is very prolific, laying up to 300 eggs in a single batch. These hatch within only a few hours, and the adults become fully developed within a few months, ready to lay more eggs. The snails come out to feed only at night, or during heavy rain, and remain hidden during the daylight. They will eat nearly anything, including leaves, rotting fruit and vegetation, young shoots, tender bark, and human and animal excrement. Even cocoanut trees are attacked, the animals climbing

to the leaves and fruit. They need plenty of calcium for their shells, and in regions where it is scarce they rasp lime from the native houses with their filelike tongues. During food shortages or dry spells, the snail can survive for many months by burrowing deep in the ground and closing the opening of the shell. Introduction of this pest into the United States, particularly in the warmer areas, would probably be most serious. Control measures have not been adequately developed, the only effective methods at present being inspection at ports of entry and decontamination of materials which might harbor the pest or its eggs.

Section IV. CHEMICAL ANTICROP COMPOUNDS

118. Plant Growth Regulators

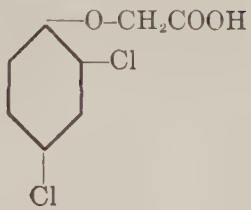
a. General.

(1) Chemical plant growth regulators include compounds such as 2,4-dichlorophenoxyacetic acid (2,4–D), 2,4,5-trichlorophenoxyacetic acid (2,4,5–T), and isopropyl N-phenyl carbamate (IPC). These compounds are effective in killing plants at rates as low as 0.05 pound per acre, concentrations that are nontoxic to man and animals. They are much more effective than the earlier contact herbicides or weed killers. There are no proven defensive measures against these compounds. By the time symptoms appear, nothing can be done to prevent the damage. The agents are detoxified in the soil after a period of several weeks to several months.

(2) Growth regulators of the 2,4–D type were first studied in 1942, and by 1950 the annual production in the United States was over 25 million pounds. They are employed extensively in agriculture for selectively controlling weeds in economic crops; in eradicating vegetation along roads, railroads, and power transmission lines; and in killing brush and weeds on range land. Growth regulators must be applied with care, since serious injury to economic crops can occur. In some instances 2,4–D applied as a dust has drifted 10 miles or more, causing serious injury to sensitive crops such as cotton and grapes.

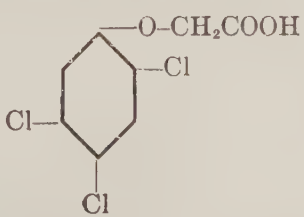
(3) The extent of plant injury from the use of growth regulators appears to depend ultimately upon alterations in the rate or direction of cell enlargement or of cell division. In addition, various biochemical processes involved in metabolism of carbohydrates and nitrogenous substances may be influenced, either with or without detectable changes in the morphology of the plant.

b. 2,4-Dichlorophenoxyacetic Acid (2,4-D).



This is a white crystalline powder with a melting point of 284° F. and a water solubility of 650 parts per million. It is commonly employed as a salt or ester. The salts are soluble in water. The esters most commonly used are the butyl and isopropyl esters, which are liquids soluble in oil and insoluble in water. For agricultural use the esters are generally applied as oil-in-water emulsions. The esters are more effective than the salts or the acid in penetrating the leaf cuticle and killing resistant species. The esters may be applied as highly concentrated sprays, and rain, immediately after application, will not reduce the effectiveness of the spray. The effectiveness of the salts in aqueous solution sprays is reduced slightly by rain that falls immediately after application, but is not reduced by rain that falls 6 hours or more after spraying. 2,4–D produces injury to all broadleaf plant species such as cotton, sweetpotatoes, beans, sugar beets, Irish potatoes, flax, nut and fruit trees, and soybeans. Plant injury may occur within an hour after spraying and usually will be evident within 24 hours. The first noticeable injury is in the stems and leaves, which twist and bend, the stems sometimes forming loops and coils. In some plants, the stems and leaves dry until the plants are completely dead; in others, the stems remain green for several weeks but may swell, develop cracks, and form callous tissue. Sometimes thick pads of tissue develop along stems and at joints. Often, numerous watery translucent buds appear at the crown but do not grow into new shoots. Several weeks after treatment, seriously affected plants may show spongy, enlarged roots. The outer portion of the root may slough off and leave wet, stringy cores that will later dry up or rot.

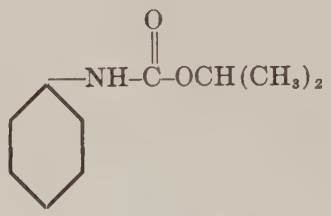
c. 2,4,5-Trichlorophenoxyacetic Acid (2,4,5–T).



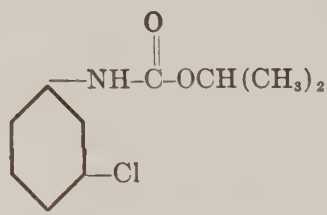
This is a white crystalline substance with a melting point of 313° F. and a water solubility of 190 parts per million. It is commonly em-

ployed as a salt or ester. The general chemical and physical properties as well as the effect on plants are similar to those for 2,4–D. There are some differences between 2,4–D and 2,4,5–T in their effectivenesss in injuring certain plant species. For example, 2,4,5–T is more effective on Irish potatoes and certain woody plants; 2,4–D is more effective on sugar beets.

d. Isopropyl N-phenyl Carbamate (IPC).



This is a white crystalline substance with a melting point of 185° F. and a water solubility of 250 parts per million. This compound affects small grains such as wheat, rye, oats, and barley; grasses; and a few broadleaf species. When IPC is applied as a soil contaminant at rates of 1 to 2 pounds per acre to small grains, substantial yield reductions may result. Generally, the compound is not absorbed by the tops of plants. Within 1 to 2 weeks after treatment, the leaves of cereals become darker green and cease to elongate. Following this the leaf tips die and the leaves progressively dry out until the plants are dead, death usually occurring within 3 weeks of the first noticeable plant injury. The 3-chloro substitution product of IPC, known as isopropyl N-(3-chlorophenyl) carbamate,



has a melting point of 104° F. and an extremely low water solubility. The technical material may be liquid at 77° F. since small quantities of impurities lower the melting point. This compound is generally slightly more effective than IPC.

119. Defoliants

a. General. While ethylene and other unsaturated compounds are known to cause defoliation (dropping of leaves) at very low concentrations, and calcium cyanamide is used to defoliate cotton plants, the most effective agents of this type at the present time appear to be ammonium thiocyanate and zinc chloride, which have been considered in paragraph 35. One-third saturated solutions of either ammonium

thiocyanate or zinc chloride are effective defoliants when sprayed on deciduous trees and also produce characteristic color changes in the leaves. They appear to be equally effective in the amount of defoliation ultimately produced, but the action begins more quickly with the thiocyanate than with the chloride. Defoliation begins on the third day, is most rapid on the fourth to fifth day, and reaches a maximum 7 to 10 days after spraying. When amonium thiocyanate is sprayed on the leaves, it changes their color from green to maple-red in 24 hours; the leaves slowly fade to brown after 9 days. Zinc chloride turns leaves a yellowish-brown color in 2 to 3 days following application, with maximum color change on the fifth day. These compounds in the concentrations used for spraying are practically nontoxic externally to man.

b. Ammonium Thiocyanate (NH_4SCN). This compound consists of colorless, deliquescent crystals, which are soluble in water and alcohol; it has a melting point of 302° F.

c. Zinc Chloride ($ZnCl_2$). This substance consists of white, granular, deliquescent crystals which are soluble in water, alcohol, glycerol, and ether; it has a melting point of 554° F. The concentrated solutions used for spraying are quite heavy. When spraying from aircraft is contemplated, this factor should be taken into consideration.

CHAPTER 7
DISSEMINATION

120. General Considerations

The term "dissemination" as used in this text refers to various procedures which might be developed and applied in launching BW attacks against man, animals, and plants. Selection of munitions, devices, and methods will be governed by the type and characteristics of the agent, the object of attack, the results to be achieved, and environmental and meteorological conditions. There are many obvious ways in which BW attacks might be attempted, including not only methods previously used for other kinds of warfare but also new or conjectural procedures which deserve consideration. Peculiar characteristics of biological agents which favor them in comparison with other types of agents are the relatively minute amounts required, since they are living and can multiply in the victim; difficulty of detection or recognition; slowness of identification; delayed action; spread or epidemic potential; and suitability for subversive or sabotage use. These properties are valuable assets in that they make possible a wide range of dissemination methods. Military personnel should be familiar with probable methods of dissemination, principles of biological attack, and properties of biological agents, so that they can promptly recognize and report a BW attack. A BW attack should be suspected whenever the enemy uses unusual methods of dissemination or unfamiliar devices which might include unusual types of bombs or shell, especially those adapted for aerosol dissemination or generation; free balloons; parachutes or other devices for dissemination of animals or insects; flasks or ampoules; or any type of weapons which produces no apparent or immediate effect. Personnel should also be alert to detect and guard against attempts at sabotage, the possibilities of which are of great variety.

121. Special Considerations

Special considerations, not applicable to other forms of warfare, should be understood when an attempt is made to provide defense against BW attack. These considerations apply to measures which might be used to surprise, confuse, or overwhelm enemy forces and are concerned with the nature of the agents used, the methods of their employment, and the vulnerability of the target. Undoubtedly, efforts would be directed toward increasing the virulence of the biological agent to the highest degree possible. Continual attempts would be made to produce strains of organisms which would be more than ordinarily resistant to antibiotic, chemotherapeutic, and other treatment methods. If possible, newly isolated disease-producing organisms or ones not ordinarily

present in the target population would probably be given serious consideration. Various combinations of similar or dissimilar agents might be employed simultaneously to hinder identification and produce more than one disease in the same individual, thus confusing diagnosis through presenting different or contradictory symptoms or periods of incubation. Attempts might also be made to use combinations of BW agents in which one helps to make the other more effective. It might also be possible, by using biological and chemical agents at the same time or in close succession, to produce infections from the BW agent more easily in individuals injured by the chemical agent. In general, attempts most probably would be directed toward exposure to much higher concentrations of an agent than would occur under normal conditions, in order to overcome natural or artificial defenses. Efforts would probably be made to effect entrance of agents through portals of entry not normally used in naturally occurring infections. Such an entrance might be accomplished through adjustment of the particle size of agents dispersed in clouds as mists or dusts. For instance, the natural method of infection in typhus, yellow, and Rocky Mountain spotted fevers is through anthropod bites and in tularemia is usually through breaks in the skin by contact with infected rabbits. However, if any of these agents were inhaled in sufficiently small particles, infection might be established by inoculation through the lungs. Inhalation of larger particles which are not small enough to enter the alveoli, or small air passages of the lungs, would result in trapping some of these particles in the upper air passages, from where they would be wafted by cilia to the mouth and pharynx; those which were not then expectorated would be swallowed, and infection might be established through the gastrointestinal tract by agents that produce such diseases as brucellosis and tularemia. It is also probable that insect vectors, such as flies, could be utilized to transmit agents of disease other than those which they have been known to carry.

122. Physical States of Agent Munitions

Since most micro-organisms are living particulate substances, there are only two possible physical states in which they can be disseminated, that is, solid forms or liquid suspensions. Solid forms could consist of dense aggregates of material, or finely divided powders or dusts, but only the powders or dusts would be effective for dissemination over wide areas in the form of clouds or aerosols. It might be possible to produce and store in dry form some pathogenic vegetative organisms or spores, which would remain viable and virulent for long periods of time. It is probable that methods could be developed to project these spores effectively against an enemy either in cloud attacks, in missiles of various kinds, or by covert or hidden methods. Liquid suspensions of organisms or spores could be disseminated as mists by suitable spray-

ing devices, generators, and explosive projectiles (as has been done with chemical agents) or clandestinely in small bottles or other containers. The toxins and chemical anticrop agents could be projected as dusts, solutions, or liquid suspensions by similar techniques. In aerosol attacks against man and animals, when a toxic agent is used which has to enter the lungs to establish an infection, effective penetration occurs only if the sizes of the aerosol particles are within certain narrow limits.

123. Overt and Covert Attack

Attack with BW agents may be classified either as overt (open) or as covert (hidden). Overt attack implies the adaptation and use of principles and methods of attack and use of weapons and munitions previously developed, known, and commonly accepted in warfare. Covert attack refers to the stealthy employment either of accepted methods or of unusual or sabotage methods which might be used before or after the actual outbreak of hostilities. While there is no direct evidence that effective methods for disseminating BW agents have been developed, there are numerous possibilities, obvious or theoretical, which deserve consideration. Both overt and covert attacks are possible from the air, from the ground, and from the sea.

124. Airborne Methods

Airplanes and, to a lesser extent, balloons could be used to disseminate BW agents by various techniques against enemy personnel, livestock, food crops, forests, installations, and cities. It is probable that spray tanks and clusters of bombs could be adapted to launch cloud attacks of BW mists or dusts from the air against man, animals, and crops and that generating devices could be dropped which would automatically function in a similar manner upon reaching the ground or surface of the sea. It would be theoretically possible to launch a covert BW attack from great distances against enemy countries by utilizing high-level prevailing winds to deliver infective agents by means of balloons or other buoyant devices. Rockets or guided missiles containing epidemic agents could be directed against areas where personnel were highly concentrated, and contaminated food materials could be dropped in agricultural regions to set up foci of infection among domestic food animals. It would also be possible to release infected insect or animal vectors of disease and agricultural pests in containers or crates equipped with parachutes and automatic opening devices. Chemical herbicides and defoliating agents could be sprayed on agricultural and forested areas by low-flying aircraft.

125. Ground Methods

Under favorable meteorological conditions, cloud attacks in the form of mists or dusts could be projected by generators against enemy per-

sonnel. These devices could be installed at fixed intervals on a stationary front or operated from vehicles moving parallel to the front. In such operations favorable winds would be required, and it would be desirable that friendly troops were protected against the agent either by protective devices or by immunization, especially if movement into the contaminated area was imminent. BW attack could be launched deep into enemy-occupied areas by shell with low-bursting charges or by rockets and guided missiles equipped with BW warheads. It even might be practicable to construct small arms missiles containing BW agents which could produce infections even in slight wounds. In withdrawal actions, disengaged areas could be sown with BW mines, or surfaces and structures could be contaminated by other methods.

126. Seaborne Methods

Cloud attacks with BW mists or dusts could be launched in the presence of favoring inshore winds, preferably at night, against enemy coastal cities or troop concentrations by means of generating or spraying devices installed on surface or undersea craft. Daylight attacks from surface craft probably would not be detectable, even if suspected by the enemy, and night attacks could not be recognized. Floating mines equipped with generating devices could either be placed by surface or undersea craft or dropped by aircraft and set to operate at a predetermined time against coastal targets. Rockets, guided missiles, and shell containing BW agents could be delivered against coastal areas and island strongholds.

127. Sabotage Possibilities

Sabotage refers to concealed or insidious action by enemy agents or sympathizers to interfere with or obstruct the defense effort of a nation. Biological warfare would appear to lend itself particularly well to such covert or undercover operations because of detection difficulties, the variety of agents and the ways in which they might be used, and the small amounts of materials required. It would be quite possible for a potential enemy nation to initiate sabotage with biological agents prior to, as well as after, a declaration of war, and such attempts might be quite effective even though the attacked nation subsequently became aware of them. The object of such covert attacks would be to kill or injure man and animals, to deplete the food supply, and to reduce a nation's capacity to defend itself or wage war by lowering morale. Some of the possible sabotage measures which might be employed against man, animals, and plants or crops are briefly considered below:

a. Against Man. Large-scale covert attacks might be attempted by utilization of prevailing winds or high altitude air masses to carry infective material or devices from areas far distant from the country

which was the object of attack. Small-scale sabotage attacks rather than large-scale attacks would appear to be more practicable, because they would be directed against small segments of the human or animal population or food crops—or perhaps against key individuals. In these operations, agents or sympathizers would be furnished secretly with infective material, or they would produce or obtain it themselves, which they could disseminate stealthily by a variety of methods. Small dusting or spraying devices could be used to introduce agent material into the ventilating systems of large office buildings, auditoriums, and theaters with little danger of detection. Infective microbes and toxins could be pumped directly into the mains of city water supply distribution systems or introduced by use of back-siphonage principles which might be applied even in private homes. Agents working in pharmaceutical establishments might be in a position to contaminate medicinal biological products. Various methods could be used to contaminate unprocessed and uncooked foods, and infective material could be placed in cooked or processed foods, such as milk, by food handlers and servers. Effective measures might also be developed to distribute pathogens on currency, stamps, and envelopes and in cosmetics, shaving soap, chewing gum, candy, and other articles.

b. Against Animals. Sabotage measures directed against domestic food animals would probably be based on efforts to set up foci of infection with agents of the epizootic type, and could be most serious where diseases were introduced against susceptible animals that had little or no protection. As pointed out earlier, the spread of communicable diseases among animals is facilitated by their herding instinct and feeding habits, and epizootics are most difficult and costly to control. Examples of such epizootics are outbreaks of foot-and-mouth disease, rinderpest, and hog cholera, which have occurred in recent years. Infective material could easily be spread by enemy agents in the form of contaminated food, in cultures or suspensions of pathogens, or by direct inoculation of scattered individual animals. It would also be possible for aircraft to drop infected food or animal vectors secretly in agricultural areas.

c. Against Plants or Crops. Micro-organisms and, to a lesser extent, pests would appear to be the biological agents of choice for sabotage. Chemical herbicides and plant growth regulators achieve their efforts by contact; since they do not multiply or spread, their use would not be practical in clandestine operations of this sort. While it might be possible for individual enemy agents to introduce plant pathogens and pests successfully, such operations would have to be undertaken with a long-range outlook, as it would probably take several seasons to establish an effective epiphytotic (plant disease epidemic) or pest infestation, even under the most favorable environmental and meteorological conditions. Anticrop agents (microbial or pest) in large amounts could be

covertly launched over wide areas by high-altitude or night-flying planes; these agents under suitable conditions could produce an epiphytotic within a few months. It should be understood that although sabotage operations against plants and crops are effective, they will probably take more time to produce effective results than would an overt attack in which larger amounts and more widespread application of the agent is employed. In the past the accidental importation of small amounts of certain plant pests and diseases from one locality to another has produced serious results over a period of years, as in the cases of the Japanese beetle, Mexican bean beetle, Colorado potato beetle, and chestnut blight. Intentional introduction of plant pests and diseases, through sabotage, might provide more dire results than the accidental introduction of them provides.

APPENDIX

REFERENCES

SR 220–180–5	Organization and Training for Chemical, Biological, and Radiological Warfare.
SR 320–5–1	Dictionary of United States Army Terms.
SR 320–50–1	Authorized Abbreviations.
FM 3–5	Tactics and Technique of Chemical, Biological, and Radiological Warfare.
FM 3–9	Staff Chemical Officer.
FM 21–5	Military Training.
FM 21–8	Military Training Aids.
FM 21–11	First Aid for Soldiers.
FM 21–40	Defense Against CBR Attack.
FM 21–41	Soldier's Manual for Defense Against CBR Attack.
FM 21–48	CBR Training Exercises.
TM 3–205	Protective Masks and Accessories.
TM 3–220	Decontamination.
TM 3–290	Individual Protective and Detection Equipment.
TM 3–350	Improvised CBR Protective Shelters.
DA Pam 8–12	What You Should Know About Biological Warfare.
DA Pam 108–1	Index of Army Motion Pictures, Television Recordings, and Filmstrips.
DA Pam 310–1	Index of Administrative Publications.
DA Pam 310–2	Index of Blank Forms.
DA Pam 310–3	Index of Training Publications.
DA Pam 310–4	Index of Technical Manuals, Technical Regulations, Technical Bulletins, Supply Bulletins, Lubrication Orders, and Modification Work Orders.
DA Pam 310–7	Index of Tables of Organization and Equipment, Reduction Tables, Tables of Organization, Type Tables of Distribution, and Tables of Allowances.
GTA 3–1	Defense Against CBR Attack.
GTA 3–2	Things to Do in a CBR Attack.
GTA 3–3	CBR Decontaminants.
GTA 3–7	CBR Duties of Sentinels (Section I—Field Sentinel; Section II—Protective Shelter Sentinel).

Abortion—Untimely birth; expulsion of the fetus before it is capable of living outside the body.

Abscess—A localized collection of pus in any part of the body, usually as the result of an infection.

Acarid—One of an order *Acarina* of arachnids including the mites and ticks.

Active immunity—Immunity resulting from the production of antibodies by the individual's own body cells in response to a stimulus provided by the presence of antigen in the tissues.

Acute—Having a short and relatively severe course.

Aerobe—A micro-organism which can live and grow only in the presence of free oxygen.

Aerosol—A suspension or dispersion of small particles (solids or liquids) in a gas (such as air). Examples are mists, fogs, and smokes.

Alkaline—Having the properties of an alkali, for example, sodium hydroxide.

Alkaloid—An organic, alkaline substance containing nitrogen, usually found in certain plants. Alkaloids are usually bitter in taste and cause marked physiological reactions. Examples are styrchnine and morphine.

Amoeba—A one-celled protozoan micro-organism that moves by finger-like processes of protoplasm.

Anaerobe—Any micro-organisms that can live without air or free oxygen.

Anorexia—Lack or loss of appetite for food.

Antibiotics—Substances produced by and obtained from living cells, usually those of lower plants, such as bacteria and molds; they are antagonistic to other forms of life, including pathogenic organisms. Examples are penicillin and streptomycin. Some may also be produced synthetically.

Antibody—A specific substance produced by the body in reaction to a specific foreign body (antigen), such as bacteria and toxins; examples are antitoxins and agglutinins.

Antigen—Any substance which when introduced in the body stimulates the formation of an antibody. Antigens are usually protein in nature and react in an antagonistic manner with specific antibodies.

Antiseptic—A substance which will inhibit the growth and development of micro-organisms without necessarily destroying them.

Antiserum—A serum containing an antibody or antibodies. It may be obtained from an animal subjected to an antigen either by injection or as the result of an infection.

Antitoxin—A substance found in the blood serum or other body fluids which is specifically antagonistic to a toxin.

Antivenin—An antitoxic serum against venom, particularly snake venom.

Aphid—A small homopterous insect which lives on plants and sucks their juices; a plant louse.

Aphthous fever—Foot-and-mouth disease; characterized by whitish spots in the mouth.

Aqueous—Of or like water; watery.

Arachnid—One of a class of arthropods, including the ticks, mites, spiders, and scorpions.

Arthritis—Inflammation of a joint.

Arthropod—One of a class of animals with segmented body and jointed legs; examples are insects, arachnids, and crustaceans.

Aseptic—Free from infection.

Asexual—Having no sex.

Attenuation—The process of reducing or weakening the virulence of a micro-organism by cultivation on artificial media or by repeated inoculation in an animal host.

Autopsy—Post mortem examination; examination of a body after death.

Avirulent—Not virulent.

Bacillus—A rod-shaped bacterium.

Bacteremia—The presence of bacteria in the blood.

Bacteria—One-celled micro-organisms which have no chlorophyl and multiply by dividing in 1, 2, or 3 directions of space.

Bactericide—Any agent that destroys bacteria.

Bacteriology—The science which deals with bacteria.

Bacteriophage—An ultramicroscopic parasitic virus of bacteria.

Bacteriostasis—Inhibition or restraint of growth of bacteria, without destruction.

Bang's disease—Infectious abortion, or brucellosis of cattle.

Biology—The science which deals with living organisms, both plant and animal.

Bipolar—Having two poles; in bacteriology, staining confined to the poles (ends) of the cell.

Botany—The science which deals with plants.

Botulism—Poisoning by botulinum toxin.

Bronchitis—Inflammation of the bronchial tubes.

Brucellosis—A generalized infection caused by one of the species of *Brucella (Br. melitensis, Br. abortus,* or *Br. suis).*

Bubo—Inflammatory swelling of a lymphatic gland, usually in the groin or armpit.

Callus—A hard, thickened area.

Capsule—A fibrous, mucoid, or membranous envelope or covering of certain organisms.

Carbohydrate—A compound composed of carbon, hydrogen, and oxygen, such as starch, sugar, cellulose, and gums.

Carbuncle—A painful, local inflammation of the subcutaneous tissue, usually larger than a boil, which later becomes perforated and discharges pus through a number of openings.

Cardiac—Pertaining to the heart.

Carrier—An individual who harbors specific disease organisms without showing symptoms, thus serving as a means of conveying infection.

Casualty—An injured, disabled, or dead individual.

Catarrhal—Pertaining to inflammation of a mucous membrane accompanied by discharge of mucus.

Cell—A small mass of protoplasm, generally including a nucleus, surrounded by a semipermeable membrane or cell wall. It is the structural and functional unit of all living organisms, plant and animal, with the possible exception of viruses.

Centigrade thermometer—A thermometer with 100° between the melting point of ice (0°) and the boiling point of water (100°).

Cereal—Pertaining to grain or the grasses which produce it.

Chemotherapy—The treatment of disease by chemicals that affect the causative organism unfavorably without seriously reacting on the patient.

Chloromycetin—An antibiotic substance derived from cultures of *Streptomyces venezuelae;* also produced synthetically. Proprietary name for chloramphenicol.

Chlorophyl—The green coloring matter of plants, by means of which photosynthesis is accomplished.

Chronic—Long continued; opposite of acute.

Cilia—Hairlike projections or lashes, found on many cells, capable of vibratory or lashing movement. They may serve as organs of locomotion for small organisms or produce a current of fluid, as in the upper respiratory tract of man.

Clinical—Pertaining to the observation and treatment of patients, as distinguished from theoretical or experimental investigation.

Cloven-footed—Having the foot divided or cleft in two or more parts, as in cattle, sheep, and swine.

Coccus—A spherical bacterium.

Coelenterates—A division of invertebrate (no backbone) animals, including corals, sea anemone, and jellyfishes.

Colitis—Inflammation of the colon.

Collodion—A syrupy or viscous solution of pyroxylin (guncotton) in ether and alcohol.

Colloid—Any substance in a state of very fine division, the colloidal state, in which the particles range in diameter from one-tenth to one-millionth of a micron. Dispersed or distributed through certain

media, colloids form so-called colloidal solutions, colloidal systems, or sols, for example, an aqueous starch solution.

Colony—A collection or group of micro-organisms in a culture; they are derived from the increase of a single organism or group of organisms. On solid culture media a colony may be visible to the naked eye.

Commensal—An organism, not truly parasitic, which lives in, with, or on another organism, and which derives benefit without injuring or benefiting its host.

Communicable—Capable of being transmitted from one individual to another.

Congenital—Existing at or before birth.

Contagious—Transmissible from one individual to another.

Contagious disease—An infectious disease capable of being transmitted from one individual to another. Many infectious diseases are not contagious but require some special method of transmission or inoculation.

Contaminate—To introduce an impurity; for instance, a foreign organism developing accidentally in a pure culture. Soil or clothing containing pathogenic micro-organisms is said to be contaminated.

Cotyledon—The first leaf or pair of leaves developing in a seed plant.

Covert—Hidden, concealed, insidious.

Crucifer—Belonging to the family of herbs including the mustards, cabbages, turnips, radishes, and cresses.

Crustacea—A large class of animals, including lobsters, crabs, shrimps, and barnacles.

Culture—A growth of micro-organisms.

Culture medium—Any preparation used for the culture of micro-organisms.

Cutaneous—Pertaining to the skin.

Cuticle—The epidermis, or outer layer of the skin.

Debilitating—Weakening or lessening of strength.

Deciduous—Falling off, or shedding at maturity or at certain seasons; deciduous trees shed their leaves in the fall, as opposed to evergreen trees which remain verdant (green).

Decontamination—Removal or neutralization of contaminating material, such as pathogenic micro-organisms.

Defoliant—Any agent which causes leaves to fall.

Dehydrate—To remove water.

Deliquescent—Having the property of taking up moisture from the air.

Demodectic—Pertaining to mites. Demodectic manges of animals are caused by the Demodex genus of mites.

Dengue—An infectious, eruptive, febrile disease of man caused by a virus and transmitted by the bite of two species of mosquitoes. Also

known as "breakbone fever," it is mainly a disease of the tropics and is marked by severe pains in the head, eyes, muscles, and joints; sore throat; catarrhal symptoms; and skin eruptions.

Dermatitis—Inflammation of the skin.

Desiccate—To dry; to remove moisture.

Devitalize—To deprive of vitality or life.

Diarrhea—Abnormal frequency and liquidity of intestinal discharges.

Diplococcus—Gram-positive, round (somewhat elongated or lance-shaped) bacteria growing in pairs.

Disease—Illness or sickness.

Disinfect—To free from pathogenic organisms or to destroy them.

Disinfectant—An agent, usually chemical, that destroys infective agents.

Dissemination—Distribution or spreading.

Droplet infection—Infection by droplets of contaminated respiratory or oral discharges dispersed in the air by sneezing and coughing.

Dysentery—A disorder marked by inflammation of the intestines, particularly the colon, accompanied by pain in the abdomen, straining, and frequent stools containing blood and mucus; dysenteries are caused by certain bacteria, protozoa, or parasitic worms, or by some chemical irritant.

Emulsion—A dispersion of fine particles or globules of a liquid in another liquid.

Encapsulate—To inclose within a capsule.

Encephalitis—Inflammation of the brain.

Encephalomyelitis—Inflammation of the brain and spinal cord.

Endemic—Native to, or prevalent in, a particular district or region; an endemic disease has a low incidence but is constantly present in a given community.

Endotoxin—A poisonous substance that is produced within a microorganism and retained within the cell until it disintegrates.

Enteric—Pertaining to the intestines.

Enterotoxin—Toxin which is specific for intestinal mucosa cells; also a toxin formed in the intestine.

Enzootic—Occurring endemically among animals; constantly present in small amounts in a given animal population.

Enzyme—An organic compound, frequently a protein, formed by living tissues, that accelerates or produces by catalytic action specific transformation of material, as in the digestion of foods by plants and animals.

Epidemic—An outbreak of disease which spreads rapidly and attacks many individuals in the same region at the same time. Analogous to epiphytotic in plants and epizootic in animals.

Epidemic spread—Rapid and wide spread of a disease from individual to individual in a given community.

Epidermis—The outermost layer of the skin.

Epiphytotic—Widespread among plants, such as certain fungal diseases. Analogous to epidemics in man and epizootics among animals.

Epizootic—Rapidly spreading and widely diffused among animals. Analogous to epidemics in man and epiphytotics in plants.

Equine—Pertaining to or like a horse.

Eruption—A rash, visible lesion or injury of the skin, caused by disease and marked by redness, prominence, or both.

Ester—A compound formed from an alcohol and an acid by the removal of water.

Etiology—The study, or knowledge, of the causes of a disease.

Exanthema—An eruptive disease or the eruption which accompanies the disease.

Excrement—Waste material discharged from the body, especially fecal matter.

Excretion—Useless, superfluous, or harmful material, particularly the urine and sweat, eliminated by the body.

Exotoxin—A poisonous substance excreted by a living organism.

Expectoration—Coughing up and discharging mucus or other fluids from the lungs and trachea by spitting.

Exudate—Any substance discharged through pores, lesions, or incisions of tissues; any substance which becomes deposited in or on the tissues by a vital process or a disease.

Facultative—Having the power to live under different conditions—opposite of obligate; voluntary; potential. A facultative aerobe is a micro-organism which is essentially an anaerobe but can grow in the presence of free oxygen; a facultative anaerobe is essentially an aerobe but can grow in the absence of free oxygen.

Farcy—The chronic and constitutional form of glanders, characterized by thickening of the superficial lymph vessels.

Fatigue—Weariness from labor or exhausting condition where cells or organs have undergone excess activity, so that they respond to stimulation with loss of power.

Febrile—Pertaining to fever; feverish.

Feces—The excrement discharged from the bowels.

Fever—Abnormally high body temperature; characterized by marked increase of temperature, acceleration of the pulse, increased tissue destruction, restlessness, and delirium.

Fibrin—A whitish, insoluble, fibrous protein, formed especially in the clotting of the blood.

Filament—A delicate thread or fiber.

Filaria—Any threadlike nematode worm of the family *Filarioidea;* parasites of blood or tissues of vertebrates.

Filtrable—Capable of passing through a bacterial filter made of unglazed porcelain or compressed infusorial earth that arrests bacteria.

The term "filtrable viruses" was formerly used to describe ultramicroscopic viruses.

Fission—The act of splitting; form of asexual reproduction in which the cell spontaneously divides into two nearly equal parts, each of which grows into a complete organism, as in bacteria.

Flagella—Whiplike appendages used to propel a micro-organism.

Fluke—Any flattened parasitic trematode worm.

Focus of infection—The localized region or chief site of a morbid (diseased) process.

Follicle—A very small excretory or secretory gland; a small cavity, for example, a hair follicle.

Fomite (fomes)—Any substance other than food which may transmit or harbor an infectious agent, such as contaminated bedding, clothing, and dishes.

Formalin—A 40-percent solution of gaseous formaldehyde in water.

Fumigation—Exposure to fumes of a chemical which destroys micro-organisms.

Fungicide—A substance that destroys fungi.

Fungus—Any one of a group of thallophytic plants, including the molds, mildews, rusts, smuts, and mushrooms; they do not contain chlorophyl and reproduce mainly by sporulation.

Gall—A swelling on plant tissues, caused by attacks of parasites, such as the gallfly and certain aphids.

Gastroenteritis—Inflammation of the stomach and intestines.

Germ—Any micro-organism, especially pathogenic; a microbe.

Germicide—Any agent that destroys germs or micro-organisms, especially disease germs.

Germinate—To sprout; to begin to grow or develop.

Glucoside—One of a class of chemical compounds consisting of a sugar molecule combined with one or more substances, many of which are poisons.

Gram's stain—A differential stain for bacteria.

Granuloma—A tumor or other abnormal growth made up of granulation tissue (small, round, fleshy masses).

Hemoglobin—The oxygen-carrying red pigment of the red blood corpuscles.

Hemolysis—The destruction of red blood corpuscles with liberation of the hemoglobin they contain.

Hemorrhage—Severe bleeding.

Hepatitis—Inflammation of the liver.

Herbicide—A preparation which kills weeds or plants.

Herbivorous—Living on plants or grasses and herbs.

Hermaphroditic—Having both male and female reproductive organs.

Heterogeneous—Composed of dissimilar elements or ingredients.

Hibernate—To pass the winter in a dormant or lethargic state.

Homogeneous—Of the same kind or of uniform quality throughout.

Homopterous—Belonging to a large order of insects having sucking mouth parts, such as cicadas, aphids, and scale insects.

Hormone—A specific chemical substance that is secreted into the body fluids by an internal secretory gland and that produces a specific effect on the activities of other organs. Examples are adrenalin and pituitrin.

Host—Any animal or plant which harbors or nourishes another organism.

Humid—Damp or moist.

Hyaline—Glassy and transparent, or nearly so.

Hygiene—The science of health and its preservation.

Hyphae—Threadlike portions or individual filaments of a fungus.

Immune—Protected against any particular disease, as by inoculation.

Immunity—The state or power of resisting the development of a disease or poison.

Immunize—To render immune.

Inactivate—To render inactive.

Incidence—The range or rate of occurrence, as of a disease.

Incubation period—The interval between the introduction into the body of an infectious agent and the appearance of the first symptoms of disease.

Infection—Invasion of body tissues by organisms, usually pathogenic, which multiply and cause disease; the presence of parasites within the body which cause injury.

Infectious disease—One which is caused by a living agent, such as bacteria, protozoa, viruses, or fungi; may or may not be contagious.

Infectivity—The quality of being infectious or the capacity of an organism to invade and establish itself as a parasite in the tissues of a host.

Infestation—Invasion by animal parasites, usually on the body surfaces of the host, without necessarily causing injury.

Inflammation—Reaction of tissues to injury, characterized by pain, heat, redness, and swelling of the affected parts.

Ingestion—Act of taking food or medicine into the body for digestion, as into the stomach.

Inhale—To breathe or draw into the lungs.

Inhibit—To arrest or restrain.

Inject—To force a fluid into a tissue, organ, or cavity.

Injection—The material which is injected.

Inoculate—To introduce a micro-organism, vaccine, immunizing serum, or other antigenic substance for preventive, curative, or experimental purposes.

Inoculum—The substance used in an inoculation.

Inorganic—Generally pertaining to chemical compounds not containing carbon, but including cyanide and carbonates.

Insect—A member of a class of small invertebrate animals, with three clearly defined body regions—the head, thorax, and abdomen; with only three pairs of legs; and usually with wings. Examples are beetles, bugs, bees, and flies.

Insecticide—An agent or material that kills insects.

Invasiveness—The ability of a micro-organism to enter the body and spread throughout the tissues; an infection may or may not result.

Jaundice—A diseased condition, characterized by yellowing of the skin and eyes and by a deep yellow color of the urine; this yellowing is due to the presence of bile pigments in the blood and tissue. Jaundice is also known as icterus.

Lacerate—To tear.

Larva—The immature, wingless, and often wormlike form in which certain insects hatch from the egg and in which they remain until the pupa or chrysalis stage.

Latent period—A period or state of seeming inactivity.

Lesion—Injury, mechanical or pathological; morbid change.

Lethal—Deadly; fatal.

Leucocyte—A white or colorless blood corpuscle; an ameboid cell which is found in the blood, lymph, and body tissues and which forms the chief cellular element in pus.

Lumbar—Pertaining to the loins (a lumbar vertebra or nerve).

Lymph—A transparent, slightly alkaline fluid found in the lymphatic vessels. It consists chiefly of blood plasma and colorless corpuscles.

Lymph gland—One of the masses of lymphoid tissue from which the lymphocytes (specific variety of leukocyte) are derived.

Lymphatic system—The system of absorbent vessels which drain the lymph from various body tissues and return it to the blood stream.

Lyophilization—The process of drying from the frozen state under vacuum.

Macerate—To soften by soaking, causing disorganization of tissue cells.

Macrophage—A large, mononuclear, fixed or wandering phagocyte cell which originates in the tissues.

Maize—Indian corn.

Malaise—A vague feeling of bodily discomfort.

Malignant—Tending to go from bad to worse; threatening to produce death.

Malnutrition—Faulty or imperfect assimilation and nutrition.

Medium (*media*, plural)—Refers to a culture medium or variety of materials and their combinations used for growing micro-organisms. It may be solid or liquid.

Meningitis—Inflammation of the meninges or membranes which envelop the brain and spinal cord.

Metabolism—The sum of all the physical and chemical processes by which living tissue is produced and maintained; transformation by which energy is made available for the use of the body.

Meteorology—The science of the atmosphere and its phenomena; the science of the weather.

Microbe—Any individual micro-organism.

Microbiology—The science which deals with the study of micro-organisms.

Micron—One-thousandth (0.001) part of a millimeter or one-millionth (0.000001) part of a meter. It is equivalent to about one twenty-five-thousandth (0.00004) of an inch.

Micro-organism—A minute living organism, usually microscopic in size.

Microphage—A small phagocyte. It is actively motile, is polynuclear, and engulfs the bacteria of acute infections.

Migrate—To move from place to place.

Millimicron—One-thousandth (0.001) part of a micron or one-millionth (0.000001) part of a millimeter.

Mite—Minute animals of the order *Acarina* (except ticks), related to spiders and parasitic on man and animals, producing various irritations of the skin. Chiggers are one example.

Molds—Filamentous fungi which produce a woolly or cottony growth on various forms of organic matter.

Mollusc—Any member of the phylum *Mollusca*, which contains most of the animals called shellfish, except the crustaceans. It comprises such animals as snails, slugs, mussels, clams, and oysters, all of which have a soft, unsegmented body, usually protected by a shell.

Morbidity—The state of being diseased. The sick rate, or the ratio of sick persons to the total population.

Morphology—The science of the form and structure of organized beings.

Mortality—The death rate; the ratio of the total number of deaths to the total population.

Mortality rate—The ratio of the number of deaths from a given disease to the total number of cases of that disease.

Motile—Exhibiting or capable of spontaneous movement.

Motor nerve—A nerve that transmits an impulse from the central nervous system or ganglion to a muscle causing movement.

Mucosa—The mucous membrane, a membrane secreting mucus, which lines passages and cavities communicating with the exterior (gastro-intestinal, respiratory, and genitourinary tracts).

Mucous—Pertaining to or resembling mucus; also secreting mucus.

Mucus—The viscid (sticky) secretion of the mucous glands.

Mycelium—The vegetative body of a fungus composed of a mass of filaments called hyphae.

Nasal—Pertaining to the nose.

Nausea—Tendency to vomit; sickness of the stomach.

Necrosis—Death of a cell or group of cells in contact with living tissue.

Nephritis—Inflammation of the kidney.

Neuritis—Inflammation of a nerve, attended by pain and tenderness over the nerve.

Neurotoxic—Poisonous or destructive to nerve tissue.

Neurotropic—Having an affinity for nervous tissue.

Node—A swelling or protuberance.

Nodular—Like a nodule or node; marked with nodules.

Nodule—A small node or lump which is solid and can be detected by touch.

Nucleus—A body within a cell which is the center of reproductive activities of the cell.

Nutrition—The process of assimilating (absorbing) food.

Nymph—A stage in the life cycle of certain arthropods, as the ticks, between the larva and adult form. It resembles the adult in appearance.

Obligate—Limited to a single life condition, as an obligate anaerobe; opposite of facultative.

Organic—Pertaining to or derived from living organisms; in chemistry, pertaining to the carbon compounds.

Organism—Any organized living being, animal or plant.

Osmosis—The diffusion of solvent which proceeds through a semipermeable membrane separating two miscible solutions and tends to equalize their concentrations.

Overt—Open; manifest.

Pandemic—Widely epidemic, affecting or attacking all or most of the population of a region.

Panzootic—Occurring pandemically among animals; attacking all or most of an animal species of a region.

Paralysis—Partial or complete loss of function; especially loss of voluntary motion and/or sensation.

Parasite—A plant or animal living on or within another living organism or host, at whose expense it is maintained.

Passive immunity—Immunity acquired by introduction of an immune serum (antibodies) produced in the body of another individual or animal.

Pasteurization—The partial sterilization of a fluid by heating to a moderate temperature (131° to 158° F.) for a definite time, resulting in destruction of certain pathogens and undesirable micro-organisms.

Pathogen—Any disease-producing micro-organism or material.

Pathogenic—Causing disease.

Pathological—Pertaining to pathology.

Pathology—The science dealing with the structural and functional changes which cause, or are caused by, disease.

Penicillin—An antibiotic compound obtained from cultures of the *Penicillium notatum—Penicillium chrysogenum* group of molds, which prevents the growth of numerous bacteria and other micro-organisms.

Peristalsis—A wormlike movement of contraction waves by which the alimentary canal propels its contents; a similar form of contraction occurs in other tubes having longitudinal and circular muscular fibers.

Peritonitis—Inflammation of the peritoneum, a membrane lining the abdominal walls and investing the viscera.

Permeable—Penetrable, refers to substances that allow the passage of fluids.

Persistency—The quality of being persistent or remaining fixed; enduring.

Pest—Any annoying or destructive animal or plant.

Phagocyte—Any cell that is active in ingesting and destroying waste and harmful bodies in the blood or tissues.

Pharmaceutical—Of or pertaining to pharmacy or to drugs.

Phenol—Carbolic acid (C_6H_5OH); a colorless crystalline, poisonous chemical compound obtained by the distillation of coal tar. In solution it is used as an antiseptic, a disinfectant, and a germicide.

Photosynthesis—The formation of carbohydrates from carbon dioxide and water by chlorophyl in plants under the influence of sunlight.

Phylum—One of the primary or main divisions of the animal or vegetable kingdom.

Physiology—The study of the functions of the living organism and its parts.

Phytotoxin—A toxin derived from a plant; ricin from the castor oil bean is an example.

Placenta—The round, flat organ within the uterus which establishes communication between the mother and the child by means of the umbilical cord. The term is also given to any cakelike mass.

Plasma—The fluid portion of the blood in which the corpuscles are suspended.

Pneumonia—Inflammation of the lungs.

Pollen—The mass of microspores (male fertilizing elements) of flowering plants.

Polyvalent vaccine—A stock vaccine made up of many strains of the same organism or different organisms.

Post mortem—Occurring or performed after death.

Prognosis—A forecast of the course of a disease; also the outlook for recovery as indicated by the nature and symptoms of the case.

Propogate—To cause to continue or multiply by generation; to reproduce; to cause to spread or extend.

Prophylaxis—Prevention of disease, or preventive treatment.

Prostration—Complete exhaustion.

Protein—Any one of a group of complex, organic, nitrogenous compounds widely distributed in plants and animals, which form the principal constituents of the cell protoplasm.

Proteolytic—Effecting the digestion of proteins by splitting them with the formation of simpler and more soluble products.

Protoplasm—The only known form of matter in which life is manifested; the essential substance of the cell. It is usually a thick, viscous, semifluid or almost jellylike, colorless, translucent material containing a large proportion of water and holding fine granules in suspension.

Protozoa—One of the lowest divisions of the animal kingdom, including one-celled organisms.

Pseudopodia—Temporary protrusions of the protoplasm of a cell, enabling it to move about or take up food.

Pulmonary—Pertaining to the lungs.

Pupa—An intermediate, usually quiescent form assumed by many insects after the larval stage and maintained until the beginning of the adult stage.

Pupate—To become a pupa.

Pus—A liquid inflammation product, made up of dead and living white blood cells, digested bacteria, tissue debris, lymph, fibrin, and serum.

Pustule—A small elevation of the skin filled with pus or lymph.

Quarantine—Isolation of infected individuals and of possible carriers and contacts for a period of time to prevent disease transmission.

Racial immunity—The resistance which all or most of the members of a species or other natural group have toward a certain infection.

Rash—A temporary eruption of the skin.

Reptile—One of a class of cold-blooded, air-breathing, vertebrate animals whose body is usually covered with scales or plates; they include the snakes, lizards, and crocodiles.

Resistance—The opposition offered by an animal or plant to a disease.

Respiration—The act or function of breathing.

Respiratory—Pertaining to respiration.

Ricin—A poisonous albumin or toxin from the seed of the castor oil plant.

Rickettsiae—Gram-negative, nonmotile, intracellular, one-celled parasitic micro-organisms, probably intermediate between the bacteria and viruses.

Rodent—Gnawing animal, such as a rat, mouse, squirrel, beaver, or rabbit.

Sabotage—Malicious waste or destruction, especially by covert means.

Saliva—A clear, alkaline, somewhat viscid digestive fluid secreted by the salivary glands of the mouth; spittle.

Salivation—A discharge of saliva.

Sanitation—The establishment of environmental conditions favorable to health.

Saprophyte—A micro-organism living upon dead or decaying organic matter.

Sarcoptic—Pertaining to Sarcoptes, a genus of acarids (mites), including the itch mite which produces scabies in man and mange in animals.

Semipermeable—Permitting the passage of certain molecules and holding back others.

Sensory—Pertaining to sensation; sensory nerves convey impulses from the sense organs to the central nervous system.

Septic—Produced by or due to putrefaction or morbid germs.

Septicemia—A morbid condition characterized by the presence of pathogenic micro-organisms and their associated poisons in the blood; invasion and multiplication of micro-organisms in the blood stream; blood poisoning.

Serological—Pertaining to serums and the study of serums.

Serum—The clear liquid which separates in the clotting of blood from the clot and the corpuscles; differs from plasma in that it does not contain fibrin. Blood serum from animals that have been inoculated with bacteria and their toxins is used in immunization.

Sheath—Botanically, the base of a leaf when covering a stem or branch, as in grasses.

Sinus—A cavity or hollow space; an air cavity in a cranial bone, especially one connected with the nose.

Solanaceous—Belonging to the nightshade family, which includes the potato, tomato, eggplant, and tobacco.

Species—A primary subdivision of a genus; a group of animals or plants which possess, in common, one or more distinctive characters and do or may interbreed and reproduce their characters in their offspring.

Spirillum—A long, rigid, curved (comma-shaped or spiral), flagellate bacterium.

Spirochete—Any long, spiral, cylindrical, flexible micro-organism which is nonsporing and motile, including those causing syphilis and relapsing fever.

Sporadic—Occurring only occasionally, not widely diffused or epidemic.

Spores—Primitive reproductive bodies or resistant resting cells, produced by some plants and some micro-organisms.

Sporulation—Formation of spores.

Stability—The ability of an organism to resist harmful physical and chemical changes in its environment.

Staphylococcus—Any of a genus of gram-positive bacteria (cocci) which often form grapelike clusters.

Sterilization—The process of killing all living cells, especially micro-organisms, by heat, chemicals, or other means.

Stomatitis—Inflammation of the mouth, usually attended by pain and salivation and often by unpleasant odor of the breath.

Streptococcus—Any of a genus of spherical, nonmotile, gram-positive bacteria, occurring in pairs or chains and dividing in one plane only.

Streptomycin—An antibiotic obtained from cultures of *Streptomyces griseus* and active against a variety of gram-negative bacteria.

Stupor—Partial or nearly complete unconsciousness.

Subversive—Tending to overthrow or destroy.

Sulfonamide—The chemical group SO_2NH_2. Sulfonamide compounds comprise a group with one or more benzene rings, amino groups, and a sulfonamide group.

Susceptibility—State of being readily affected or acted upon.

Symbiosis—The living together or close association of two dissimilar organisms, usually with benefit to one or both.

Symptoms—Functional evidence of disease or of conditions; or a change in condition indicative of some mental or bodily state.

Synthesize—To build up a chemical compound by a union of its elements.

Terramycin—A crystalline antibiotic isolated from a soil fungus, *Streptomyces rimosus,* of low toxicity and effective against a wide variety of micro-organisms.

Tetanus—An acute infectious disease caused by a toxin produced in the body by the bacillus *Clostridium tetani.*

Thallophyte—A simple plant, not differentiated into roots, stems, and leaves; a member of the division of the plant kingdom which includes algae, fungi, lichens, and bacteria.

Therapeutic—Pertaining to the science and art of healing.

Therapy—The treatment of disease; therapeutics.

Thermophilic—Growing best at elevated temperatures; said of bacteria which develop best at a temperature of 104° F. (40° C.) to 158° F. (70° C.). Examples are bacteria found in milk, fermenting manure, and hot springs.

Thermostable—Not easily affected by moderate heat.

Thorax—The chest; the portion of the body between the neck and abdomen.

Tissue—A group of specialized cells united in the performance of a particular function.

Toxemia—A general poisoning or intoxication due to absorption of bacterial products (toxins) formed at a local source of infection.

Toxic—Poisonous; pertaining to, due to, or of the nature of, a poison.

Toxicity—The quality of being poisonous or especially the degree of virulence of a toxic microbe or poison.

Toxin—Generally any poisonous substance of microbic, vegetable, or animal origin. True toxins are of a proteinlike nature, more or less unstable, require a period of incubation or a latent period to produce symptoms, and induce in suitable animals the formation of specific antitoxins.

Toxoid—A detoxified toxin, changed so that it is no longer poisonous, but still antigenic and producing active immunity when injected.

Translucent—Partly transparent; admitting passage of light but diffusing it so that objects beyond cannot be clearly distinguished.

Trypanosome—Any of a genus of parasitic flagellate protozoons infesting the blood of various animals, including man, and usually transferred by the bite of an insect.

Tuber—A short, fleshy, usually underground stem or shoot having small scale leaves with buds or eyes in the axils, as the potato.

Udder—A mammary or milk gland, when large, hanging, and provided with two or more nipples or teats, as in cows.

Ulcer—A superficial sore, discharging pus; usually located on the skin or mucous surface.

Ultraviolet—Beyond the violet end of the spectrum; said of rays or radiation between the violet rays and the roentgen rays.

Unicellular—Made up of a single cell.

Uredospore—One of several types of spores produced in the life cycle of a rust fungus, being formed in pustules which become exposed by rupture of the cuticle of the host; repeating summer spore.

Vaccination—Protective inoculation with micro-organisms, killed or attenuated; protective inoculation against smallpox by inoculation with vaccinia (cowpox) virus.

Vaccine—A preparation of killed or attenuated infective agent used in inoculating to produce active artificial immunity.

Vascular—Pertaining to, or filled with, vessels.

Vector—A carrier, especially the animal or host that carries the pathogen from one host to another, as the malaria carrying mosquito.

Vegetative—Concerned with growth and nutrition—not with reproduction.

Vegetative cells—Nonsporeforming bacteria or sporeforming bacteria in their nonsporing state.

Vesicle—A small sac or bladder containing fluid; a small blister.

Veterinary—Pertaining to the science and art dealing with the prevention, cure, or alleviation of disease in animals.

Viable—Capable of living and developing.

Vibrio—A short, curved, rod-shaped bacterium motile by means of one or more polar flagella.

Viremia—Presence of virus in the blood.

Virulence—Disease-producing ability; the relative infectiousness of an organism.

Virulent—Exceedingly hurtful, venomous, deadly.

Virus—A minute infectious agent, smaller than bacteria, capable of passing through filters that will retain bacteria and of multiplying only within a living susceptible host cell.

Viscera—Large internal organs in any one of the three great cavities of the body, especially in the abdomen.

Vomitus—Matter vomited.

Zoology—The branch of biology dealing with animals.

Zootoxin—A toxin or poison of animal origin, such as venom of snakes, spiders, and scorpions.

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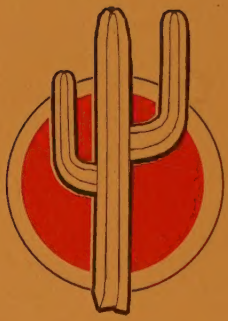

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